Crop Histories

by

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Part One

An Ecological View of History

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Parts of this book were used in my Farming and Us; The Influence of Agriculture on Human Behaviour*, as well as in* Return to Resistance*, both of which are available as free downloads at www.sharebooks.ca. Readers who are familiar with these earlier books will find repetition, and they are asked to be patient with sections that are already familiar. This repetition was considered preferable to the irritating practice of referring new readers to another book.*

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Chapter One

The Wild Ecosystem

History can be studied from various points of view. Old fashioned history, as school children knew to their cost, involved memorising dates, kings, and battles. During the nineteenth century, it became fashionable to base popular history books on famous people, and these books were largely biographical. More recently, historians became involved with the social, economic, and other aspects of history.

In this book, I attempt to look at history from the point of view of a biologist, an ecologist, and an agriculturist. Indeed, it is my simple contention that, without crops, there would be no civilisation, no perceived history, and no historians. And, just as a single battle, or a single death, has sometimes changed the course of history, so the presence or absence of a single wild species of plant has occasionally changed the course of human affairs out of all recognition.

The Importance of Grass

At about the time that the dinosaurs became extinct, some sixty five million years ago, a new kind of plant appeared on the evolutionary scene. This was the grass family, and its arrival had a profound effect on the evolution of the mammals, including the evolution of people.

Grass leaves are unusual in that they grow from the base, not the tip. This means that a grass plant can lose most of its leaf tissue to a grazing animal, without its growing points being destroyed. Many grasses can grow new leaves at a rate of an inch or more a day, and they recover quickly from having their leaves eaten. Equally, as every gardener knows, turf grasses can be mown without the turf being ruined. And, with good growing conditions, they can become a positive nuisance, because they grow so fast, and they must be re-mown so frequently.

Because they could stand up to grazing so much better than other plants, grasses soon became the dominant plants in vast areas of grasslands, now called savannas, prairies, pampas, and steppes. In its turn, this domination led to an explosive evolution of grass-eating, grazing mammals. And this abundance of mammalian herbivores led also to the evolution of superbly efficient hunting carnivores, such as the big cats, wild dogs, and, eventually, humans.

The old aphorism says that all beef is grass. But all lamb and mutton is grass too, and so are horses. So are wool and leather. So too is cane sugar. And, insofar as the most important foods in the world are cereals, all people are grass as well. Without grasses, there could have been no explosive evolution of mammals and, hence, no evolution of people. Furthermore, as will become clear shortly, without the *cultivated* grasses, the cereals, there could have been no agriculture and, hence, no civilisation.

It is becoming popular these days to say "We are what we eat" and this is used as one of the many justifications for modern organic farming and organic food. Alas, this comment is a fallacy. If it were true, we could say that, because all beef is grass, vegetarians can eat beef. The fallacy lies in the fact that all living things are much *more* than just what they eat. All living things have the ability to synthesise mere food into highly complex living tissue, and to use mere food as a source of energy. So it is incorrect to say "We are what we eat". To be accurate, we must say that we are much more than what we eat. However, this does not in any way detract from the value of organic food.

The Carrying Capacity of the Environment

Before the development of human culture, our remote, hominid ancestors lived as a wild species. They were a mere component of a natural ecosystem, and just another link in a food chain. Originally, these ancestors of ours were gatherers of plant food, and their behaviour and living habits were very similar to those of modern chimpanzees. That is, they could eat fruits, seeds, berries, nuts, and various leaves. But they could not eat grass. They would also eat animals, including insects, on the rather rare occasions when they could catch them. Their total food supply restricted the size of their population, and there was a strict limit to the amount of food that the

wild ecosystem could produce. This limitation is known as the *carrying capacity of the environment*. A good environment might have required two or three square miles of territory to support one adult hominid, while a less suitable environment would require twenty five or more square miles to support one adult.

If the hominid population increased beyond the natural carrying capacity of the environment, there were really only three alternatives. One was that the surplus hominids died, possibly from starvation or, more likely, in those cave-man days, from being caught, killed, and eaten by one of the large carnivores. A second alternative was for the surplus hominids to steal territory from their neighbours, and this meant war, which was just as likely to be lost as won. A third alternative was to migrate to another, uninhabited area, if one could be found.

Throughout our prehistory, this pressure to migrate was so strong that pre-historic people discovered and colonised virtually every habitable place in the entire world. The only land surfaces that remained uninhabited were the polar ice fields, deserts, the tops of high mountains, and oceanic islands too remote to be reached in primitive boats.

Three Brutal Laws of Nature

When an ecologist looks at our pre-history, he is usually struck by the dominating influence of three brutal laws of nature. These laws are brutal from the point of view of the individual, but they are basic to the survival of the species. Indeed, evolution could not occur without them.

The first brutal law of nature states that, for any wild species, the carrying capacity of the environment really is limited. Throughout the entire history of evolution, which has lasted some three and a half *billion* years, only one species has

been able to increase the carrying capacity of its environment to any significant extent. That species is *us*.

In ecological terms, this is the fundamental difference between us and wild animals, between civilisation and “nature red, in tooth and claw”. Any wild species is a mere component of a wild ecosystem, and it is totally controlled by that ecosystem. Our own species has reversed this situation. To a very large extent, our ecosystem does not control us. We control *it*.

The second brutal law of nature states that the total environment, the total living space, available to any species, is strictly limited. The area of land available to a terrestrial species, or the volume of water available to an aquatic species, cannot be increased. There are further restrictions superimposed on these absolute limits. These restrictions are mainly climatic, such as temperate and tropical, but they may involve other factors, such as sea water versus fresh water, acid soils versus alkaline soils, and so on. Obviously, a tropical species cannot survive a temperate winter, and a rain forest species cannot survive in an arid area.

The third brutal law of nature states that all species reproduce in *excess* of the carrying capacity of their environments. This means that the total living space of a species is always fully occupied. Indeed, surplus reproduction is essential to long-term survival. In evolutionary terms, over-population may be wasteful, but under-population is disastrous because, if prolonged, it leads to the extinction of that species. Because no species can exactly match its reproduction to the carrying capacity of the environment, all species have to play it safe, and reproduce excessively. It is axiomatic that every species that still exists must be reproducing excessively, because any species that had failed to do so would have become extinct.

If reproduction exceeds the carrying capacity of the environment, as it invariably does, the weak must go to the wall. In fact, this is the basic mechanism of

evolution. This mechanism is often called the survival of the fittest, but it is perhaps more accurate to describe it as the elimination of the least fit. The resulting struggle for existence is the driving force behind the whole of evolution.

The Hunger Compulsion

These three brutal laws of nature lead to an environmental influence so important that it overrules all other factors. We might, perhaps, call it the *hunger compulsion*. Most modern people have never experienced prolonged malnutrition, or desperate hunger, let alone starvation. They have undoubtedly experienced a strong and healthy appetite, on many occasions. They have also experienced the pleasure of feeding that appetite and, probably, the frustration of waiting for a delayed meal when they are really hungry. But relatively few people alive today have experienced the utter despair of an enduring, excruciating hunger that cannot be assuaged.

Hunger is, without question, the most *compelling* of motives. It is a far more compelling motive than, say, sex. People can survive without sex, and without coming to serious harm, for years, if absolutely necessary. But try surviving for a week, or even a couple of days, without food. Hunger will very quickly drive the most virtuous of people to desperation, and to any of the known crimes, ranging from minor theft to brutal murder, and even cannibalism.

There are other human compulsions, of course, such as the desire for shelter, land, money, or power. There are also the compulsions of various human emotions such as anger, even rage, or love for a lover, or concern for children, or just plain lust. But none of these compulsions, powerful though they may be, can be quite as compelling, or quite as urgent, as the compulsion of hunger.

This, then, was the rock bottom, biological basis of hominid and human pre-history. There were always too many individuals, because our remote ancestors,

indeed *all* our ancestors, like all other species, consistently reproduced beyond the carrying capacity of their environment. Hunger, caused by over-population, would force the surplus individuals to one of those three grim alternatives. They had to migrate to a new, unoccupied territory, if one could be found, or they had go to war in order to conquer territory from their neighbours, or they had to die, quite possibly because *their* neighbours had decided to conquer *them*. There is not the slightest doubt that all three alternatives were predominating factors throughout our prehistory, and that life for these primitive people often was "nasty, brutish, and short".

Hunger is not only the most compelling of motives. It is absolutely the first, and the most important, consequence for any species that reproduces beyond the carrying capacity of its environment, and which exceeds the critical population density. Because every species does reproduce excessively, there is no need whatever to postulate any other root cause of hominid migration and human warfare. Nor is there any need to postulate any other origin of human cultural evolution. All of our efforts to dominate our environment derive ultimately from the absolute necessity of preventing hunger, and of eliminating even the fear, and the threat, of hunger.

Human civilisation developed because, for *intelligent* beings, there were three additional alternatives. These additional alternatives involved the vanquishing of each one of those brutal laws of nature. One of these alternatives was to use intelligence to increase the carrying capacity of the existing environment. The second was to use intelligence to make tolerable an alternative, but otherwise inhospitable, environment. The third was to use intelligence to restrict the growth of the population.

The First Alternative

This species of ours originated in Africa. It was there that our remote ancestors began to evolve an intelligence and, with it, a culture, that far surpassed the

proto-cultures of other social mammals, such as chimpanzees, baboons, rats, or wild dogs.

No wild species has ever been able to increase the carrying capacity of its environment to any significant extent. However, when our own species stopped being totally wild, and began very slowly to develop its culture, a fundamental change occurred. With the beginnings of culture, our remote ancestors began to modify the natural ecosystem to their own advantage. They began to convert it into an artificial ecosystem, controlled by themselves to suit themselves. And, by doing this, they began to increase the carrying capacity of their environment.

Our remote ancestors began using their intelligence to increase the carrying capacity of their environment rather more than two million years ago. They started by using and, later, by *making*, stone tools. This enabled them to become regular meat eaters. They probably began their meat eating by scavenging abandoned bones left by wild carnivores, and by using stones to break open bones that wild carnivore jaws could not crack. Later, they made and used stone tools that enabled them to hunt themselves, cooperatively, and very intelligently. These two developments of tool-using and tool-making changed these plant-eating hominids into hunters of quite devastating skill. From being mere gatherers of plant food, our ancestors became scavenger-gatherers and, later, hunter-gatherers. Volume for volume, meat is about twenty times more nutritious than plant foods, particularly raw plant foods, and this development of meat-eating was the first major increase that our ancestors made in the carrying capacity of their environment.

Possibly as early as one million years ago, our ancestors discovered how to tame and use fire. This produced further increases in the carrying capacity of their environment. With the taming of fire, came the art of cooking food. This greatly increased the variety of plant foods that could be eaten, their digestibility, and their

nutritive value. Cooking also destroys many human pathogens and parasites that are carried by both raw vegetables and raw meat. It is probable that human health improved accordingly. Fire is also a wonderful protection against wild carnivores, as anyone who has slept in a tent in the African bush will know.

At an undetermined, but relatively recent date, many people became herders. They lived in association with a herd of wild herbivores and, after many generations of both the herders and their herds, a mutual dependence developed. The people protected the herd from wild carnivores, but they also utilised surplus animals for food. This early process of animal domestication is discussed in more detail in the next chapter.

A mere ten thousand years ago, the world population of humans became so large that there were no unoccupied areas left to colonise. Our over-populated ancestors then made dramatic new increases in the carrying capacity of their environment. They invented agriculture, which is the main topic of this book. As a result of all these various increases, the carrying capacity of our environment today is about one *thousand* times greater than the environment of our plant-gathering, pre-scavenging, pre-hunting, hominid ancestors.

The Second Alternative

In spite of having increased the carrying capacity of their environment by becoming hunters and meat-eaters, these hunter-gatherer ancestors of ours continued to reproduce in excess of that carrying capacity. No doubt, war and premature death remained important factors in culling their numbers. But hunger must have remained the dominant driving force in their lives. It was excessive reproduction, and the resulting hunger, that forced our ancestors to migrate out of tropical Africa and to find new living space in temperate Europe and Asia. They did this by using their

early cultural achievements to survive in what must have been horribly uncomfortable temperate regions, during horribly uncomfortable temperate winters. They survived these winters by the inventions of building and clothing, and by the use of fire.

Caves were always popular shelters, as any archaeologist knows well. The problem with caves, however, is that there are not enough of them, and they are least common in the open grasslands that our hunting ancestors preferred. So these ancestors invented building. Their first buildings were undoubtedly quite primitive structures of sticks and animal skins, and they have left no archaeological remains. They would have been temporary structures because hunter-gatherers are nomads, and they are compelled to move from one area to another at frequent intervals. Permanent buildings were neither needed, nor produced, until after the discovery of agriculture.

The first clothing undoubtedly consisted of animal skins and it probably dates from the first hunting, as opposed to the first scavenging. Nevertheless, clothing was essential if our hairless ancestors were to colonise temperate areas, and to survive winters.

Fire provides warmth, and this too assisted our tropical ancestors to migrate into cooler, temperate areas. The use of fire not only increased the carrying capacity of their existing environment by allowing cooking. It also increased the total living space available to primitive people by making new, but colder, areas habitable.

Tribes of industrially undeveloped peoples always took great care in maintaining their family fires at all times. They had special rules and rituals that a family must follow, should their fire go out. These rules were similar to the rules of royal succession, and they ensured that the tribe as a whole, or the clan, was always in possession of an heir, and in possession of fire. A lost fire had to be renewed from

the fire of a father, or an older brother, and so on. The collective, tribal fire had probably burned continuously for centuries, if not millennia, having originated in a single flash of lightning. This careful nursing of fire may seem a strange custom to us, because we are so familiar with matches, lighters, and other methods of starting fires. But, to people who had none of these things, the total loss of their fire would threaten cold and starvation.

The ability to survive cold increased our total environment dramatically. When one area became crowded, a new, uninhabited territory could be found without too much difficulty. Colonisation of the huge land mass of Europe and Asia represented an enormous increase in the total environment of our early ancestors, and it occurred about one million years ago. Colonisation of the Americas represented a comparable increase, but it was very recent.

Migration into the Americas

During much of the last ice age, the Bering Straight was dry land, because the sea level would fall by as much as 100 metres when so much water was locked up in huge polar ice caps. At that time most of the northern part of North America was covered in permanent ice, and this would have made human migration into the New World impossible. However, there was an ice-free corridor stretching from Alaska, down the eastern side of the coastal mountain range, to more hospitable areas. This corridor separated the Cordilleran ice sheet that covered the west coast mountains, from the Laurentide ice sheet that covered the huge area surrounding Hudson Bay. Both of these ice sheets were part of the Wisconsin glaciation, which was the final glaciation of the last Ice Age. There were considerable fluctuations in the intensity of the cold, and during one of the warmer periods, this ice-free corridor may have permitted human migration.

The ice-free corridor was produced by winds called chinooks. As winds from the Pacific Ocean rise over the mountains, the air expands, gets cold, and precipitates moisture. As the dry air descends the east side of the mountains, the opposite effect occurs. The descending air is compressed and it gets warm, producing winds called chinooks, named after the Chinook Indians. These chinook winds are so warm that they are locally known as "snow-eaters". In Libya, such winds are called *ghibli*; in Germany, where they come off the lee of the Alps, they are called *föhn*; and, east of the Andes, in Argentina, they are called *zonda*. It was these chinooks that were responsible for the ice-free corridor which provided the most likely route for the first entry of humans into North America, towards the end of the Wisconsin glaciation, some fifteen thousand years ago.

The only realistic alternative is to assume that these early colonisers came by sea, probably in skin boats, and relying almost totally on the seashore for food. Unfortunately, any archaeological remains that such people might have left, along the coast of the Pacific Northwest, have been submerged by the rising sea levels that occurred with the melting of the Ice Age glaciers. This alternative possibility must accordingly remain conjectural.

There is convincing archaeological evidence from the Pedra Furada rock shelter, in Brazil, however, which reveals human habitation dating from 32,000 years ago. It seems that these people could have reached South America only by sea, in primitive boats that made a very long series of short journeys down the west coast, some 40,000 years ago. Presumably, the mountainous west coast of North America was uninhabitable during this period of the Ice Age. These seashore inhabitants would have had little incentive to migrate inland until they reached the tropics.

There is also evidence that the beautiful Clovis spear-points of pre-historic America were derived from a European culture. It is thought that early Europeans

may have travelled along the southern edge of the ice field that stretched across the Atlantic during the Ice Age, living much as the Inuit (Eskimo) people did until quite recently. This would mean that the Clovis point people were of European rather than Asiatic origin.

Whatever their route, and time of arrival, these colonisers of the Americas were still hunter-gatherers, and their population densities could still be measured only in terms of the number of square miles of territory needed to feed one adult.

The Third Alternative

Their intelligence enabled our ancestors to conquer the first brutal law of nature, and they succeeded in increasing the carrying capacity of their environment very considerably. They also conquered the second brutal law of nature. They increased their total environment, and they did so dramatically.

However, to this day, we are still being defeated by the third brutal law of nature. We continue to reproduce in excess of the carrying capacity of our environment, and there is no unoccupied, habitable land left for surplus people to colonise. During the twentieth century, the world population increased from one and a half billion to six billion. This means that we have had to quadruple our agricultural production, and the carrying capacity of our environment. It is doubtful whether we can increase it very much more, and this rather horrible prospect is known as the world food problem.

We may be able to increase food supplies in other ways, making use of new techniques that are still undiscovered (Chapter 22). But then other environmental factors are likely to become limiting. These factors include shortages of energy, timber, fresh water, oxygen and, eventually, standing room on the planet. Long before that, various kinds of pollution will have made our planet uninhabitable. There

really is an ultimate limit to the carrying capacity of our environment, in spite of our intelligence, and in spite of our apparently endless potential for increasing that carrying capacity in the past.

People often suggest that we can solve the over-crowding problem by migrating to other planets. But, even if we manage to develop space travel, and space living, sufficiently to colonise other planets that are habitable, this will not solve our problem. Space travel involves small founder populations only, and it does little to relieve the existing population pressure on our own planet. There can be no question of moving billions, or even millions, of people to another planet.

Over-population and hunger are *still* the most important problems facing the human species. If we do not stabilise our population growth soon, billions of people are likely to die of starvation. This is possibly the most horrible way of dying. And, if such a disaster should occur, our lives will once again become nasty, brutish, and short.

The answer to that third brutal law of nature is thus to control the size of our own population. Indeed, there is little doubt that this is now the only alternative left to us, if we do not want to lose our entire civilisation in a welter of over-crowding, pollution, and starvation. Some would argue that this welter has already started.

Primitive human societies could do little in the way of family planning when over-crowding and starvation became grim realities. The most obvious method is to abstain from sex, once each parent had produced the permissible number of children. But it is entirely unrealistic to expect an entire human population to do this, however sincere their family planning convictions may be. Infanticide was the most common method of restricting family size and, sadly, it was usually the little girls who were killed. In times of scarcity and danger, boy children are more valuable because they

are future warriors who can both defend their territory and, perhaps, conquer their neighbours' territory. A preference for boy children is widespread to this day.

In a modern distortion of infanticide, the sex of an unborn foetus can be determined by ultrasound and, if the foetus is the wrong sex, it can be aborted. Sadly, once again, it is usually the female foetuses that are aborted and, as a result, in parts of India and China, males out-number females by nearly ten percent. This does not make for a peaceful or happy society, whatever one's views on abortion.

During relatively recent times, crude contraceptive devices began to be used, including vaginal sponges and condoms made from sheep gut. It was only quite recently that contraceptive devices and drugs became really effective, and easy to use. Future improvements can confidently be expected. The advent of AIDS has given a new urgency to their use, and this urgency will soon ensure that only the most keenly desired of conceptions will occur. In its turn, this could lead to a reduction of abortion and, even more important, a reduction in the numbers of *unwanted* children. It is these unwanted children who are likely to grow up unloved, emotionally insecure, neurotic, even psychotic, and criminal.

Given the enormous difference between civilised behaviour and the brutal laws of nature, the controlling of our population size is, beyond question, the most fundamental contribution we can make to further progress in our civilisation. It is also the most fundamental contribution we can make to preserving our civilisation. We have increased our total environment to the utmost limits of the available, habitable land. And we have increased the carrying capacity of that environment close to its utmost limits also. If we are finally to escape the consequences of these first two brutal laws of nature, we must vanquish the third brutal law also, and stop reproducing beyond the carrying capacity of our environment.

It is entirely possible that a new morality, a new ethic, will develop from an ecological consideration of the human situation. That every normal human being should be entitled to have children is indisputable. That all of us should be entitled to have as many children as we want is frankly absurd. Indeed, it is downright dangerous. This is a freedom that can be justified only if we want to abandon everything we understand by civilisation, and only if we want to return to the law of the jungle.

Every human individual should be entitled to a certain minimum share of the total environment. That minimum should be adequate to provide a comfortable and healthy existence in peace and security. Parents who produce children in excess of the permissible maximum are, in effect, claiming more than their share of the total environment. This is theft, pure and simple. The law of the jungle, of course, is based on theft, and on competition that is ruthless to the point of killing your competitors, either directly or indirectly.

It will probably seem incredible to our descendants that, at the beginning of the twenty first century, conservatives were still opposing this simple and irrefutable logic. The most prominent of these conservatives are the reactionaries of the Catholic Church. Future Church ecclesiastics are going to have a difficult time explaining how their Church could be so closed-minded that it encouraged population increases beyond the carrying capacity of our environment, to say nothing about encouraging the spread of AIDS. The Catholic Church is doing this by prohibiting contraception, and by prohibiting the use of condoms. And it is doing so on the basis of an obscure argument that, to a non-Catholic biologist, can only be described as theological hair-splitting.

Some of the more extreme feminists also seem to think that the total available land for human habitation is unlimited, and that the carrying capacity of that land is

also unlimited. They insist that every woman has an absolute right to have as many children as she wants. Only male chauvinists will disagree with the feminist claim that a woman should have control of her own body. But it is only the female chauvinists who are so egocentric as to claim more than their fair share of the environment. *No one* has a right to bring children into a world where they are going to starve to death. Equally, *no one* should be allowed to contribute to those starvation conditions by an irresponsible procreation.

The Thirst Compulsion

In addition to the hunger compulsion, there is a very real thirst compulsion. At first sight, it might appear that the thirst compulsion is even more compelling than the hunger compulsion. After all, we can survive without food for a few weeks, but we can survive without water for only a few days.

As a matter of fact, and contrary to our first reaction to this question, the thirst compulsion was usually much less important than the hunger compulsion, because water was always more plentiful than food. Except in rather rare circumstances, drinking water was not a limiting factor in the human environment.

When water shortages were important in human affairs, it was because of their effect on the growth of wild or agricultural plants, and on food production. In other words, most rain failures and water shortages led to a failure of agriculture, and a shortage of *food*, but there was usually enough water for drinking. The thirst compulsion was not important, it seems, when compared to the total domination of both pre-history and history by the hunger compulsion.

However, as our population is increasing, the total supply of clean, fresh water is actually decreasing, because of pollution. This pollution includes atmospheric pollution that produces dirty, usually acid, rain, as well as ground water and river

pollution, with all the by-products of agriculture and industry. It is entirely possible that the thirst compulsion will become an important factor in human affairs, at least in some areas, in the not too distant future.

Starvation

There was a famine, once, in Ethiopia, and a mother with seven children arrived at a remote, famine refugee camp. Needless to say, none of the several fathers of these seven children was around to help in this time of crisis. Unfortunately, there was some doubt whether the international convoys, bringing famine relief, would get through in time, because they were being delayed by political malice. On one occasion, one of the youngest of these seven children had been given a rare piece of bread. The desperate mother was seen to snatch this bread from her child, and to eat it herself. When asked how she could steal food from her own child, she replied that, if one her children died, it would, of course, be a tragedy; but that, if the mother of her seven children died, it would be a disaster. This all made little difference, in the end. The international aid convoys did not get through and, three weeks later, all of these poor people had died of starvation.

It is difficult to describe the agony of starvation. The ancient Greeks used to ask how can one describe the pain of a scorpion sting, except to someone who has already experienced it? Starvation is hunger so acute that it is pain. This pain is constant. It never goes away. It is accompanied by a sense of utter despair. This despair is caused by the knowledge that there is no food. There will be no food available tomorrow, or the day after, or the day after that, or ever. It takes rather a long time to die of starvation.

Chapter Two

Domestication

The Environment

Before the beginning of civilisation, our hunter-gatherer ancestors were little more than wild animals. They differed from wild animals only in that they had used their intelligence to increase their total environment, and to produce small, but important, increases in the carrying capacity of that environment. However, they were still a mere component of a natural ecosystem, and they had little control over that ecosystem. And they themselves were powerfully controlled by their ecosystem, and their environment, which determined quite literally whether they lived or died.

The theme of this book is that the development of civilisation depended entirely on the quality of the local environment, and that it did *not* depend on the quality of the humans who happened to inhabit that environment. The human factor is, and, during the last ten millennia, always was, a constant. We are all one species and, given a suitable environment, and adequate time, any human population has the potential to develop a great civilisation from scratch.

The development of any civilisation depended on the domestication of wild animals and plants. But civilisation could develop only if the environment possessed wild animals and plants that were suitable for domestication. Many environments did not possess any such plants or animals. The tropics, for example, contained quite different species from the temperate regions. And the New World species were very different from those of the Old World.

When Darwin developed his theory of evolution, he also recognised the process of domestication. And he recognised that it differs from natural selection only in that it results from *artificial* selection. It is people, rather than nature, who decide which individuals are to become the parents of the next generation of their domestic plants and animals. And, although their selection involves the fittest individuals, this fitness is not defined by the needs, or the survival, of the species in question. It is defined by the needs of the people who are doing the selecting and, usually, that selection is very much to the disadvantage of the species being domesticated.

In general, domestication does not produce new species. But it often produces variants which have been changed so much that their wild progenitors are difficult to recognise. And many of these variants have been changed so much that they are entirely incapable of surviving on their own in a wild ecosystem. They are totally dependent on people for their survival.

Cultural Evolution

Biologists recognise three kinds of evolution. The first is Darwinian, or natural, evolution. This evolution is based on natural selection, and the survival of the fittest. It produces genetic changes that lead, eventually, to new species. And it has continued since the beginning of life, some three and a half billion years ago. The second kind of biological evolution is cultural evolution, and it can occur in any social species in which the young can learn from their elders. The third kind of evolution is a combination of the first two, and it is called domestication. It is based on artificial selection, and it too leads to genetic changes. But, obviously, it is possible only if there is an advanced cultural evolution.

Darwinian evolution is based on genetics, and its progress is represented by new genetic code. Cultural evolution is based on memory, and its progress is

represented by new knowledge. Cultural evolution also represents the current climax of Darwinian evolution, because it is possible only in the most highly evolved species.

Cultural evolution occurs in social species, such as wild primates or wild dogs. But it cannot occur in all social species. In insect societies, such as bees, ants, and termites, the young have neither the means, the ability, nor the opportunity, to learn from their elders. Their lives are too short, and their brains are too small. And their generations may not overlap. Their elders are usually dead before the young would have had any significant time to learn from them, assuming these elders had anything to teach, which is unlikely. Insect societies consequently operate entirely on the basis of inherited behaviour patterns, and on memory gained from individual experience.

The key feature of cultural evolution is that it involves the growth of a social memory, as opposed to an individual memory. An individual memory lives only so long as the individual lives, and it dies when the individual dies. But a social memory, communicated from generation to generation, can both survive and grow, from generation to generation, and it can live indefinitely.

Modern wild primates, and various wild species of dogs, rats, and other social mammals, including whales and dolphins, have primitive cultures called proto-cultures. But we are the only species that has developed major cultures, which have transformed entire ecosystems, changed the face of the Earth, and left footprints on the moon. Our cultural developments began very slowly, rather more than two million years ago. And they have been growing ever since at an exponential rate. That is, the rate of increase has itself been increasing. This means that the time from one major discovery to the next is reduced with each discovery. There is no doubt that the rate of new discoveries in the twentieth century has been bewilderingly, even frighteningly, fast.

Nevertheless, it was our cultural evolution that enabled us to increase the carrying capacity of our environment, to increase our total living space, and to domesticate other species, to their own disadvantage, and to our own advantage.

Domestication

In the broadest terms, domestication is the replacement of natural selection with artificial selection. Geneticists talk of selection pressures, which may be either natural or artificial. Selection pressures operate on populations, and the word pressure is used in the sense of persuasion, of bringing pressure to bear. Selection pressure favours certain individuals in the population, and their chances of survival and reproduction are then enhanced. A strong selection pressure can change a population out of all recognition in only a few generations. However, because most wild populations are in a good state of balance with their environment, change is unnecessary, and the selection pressures are slight. The changes are then few and slow.

As we have just seen, domestication means that the selection pressures are artificial, and they are imposed by people. This process was often unconscious, and it was no more than selecting as parents the best individuals for a given function. The many different breeds of dog, for example, indicate how many ways a wild species can be changed, in order to fulfil many different functions. It is no accident that most breeds of dog are associated with hunting, usually in a rather specialised way. And few breeds of domesticated dog could survive on their own in the wild, unless they reverted to their original wild form.

The Domestication of Animals

The first domestication involved animals, and important animal domestication occurred mainly in the Old World. Wild animals suitable for domestication were generally lacking in the New World.

Ancient people began to live in association with herds of wild herbivores. These people became herders. They protected the herd from wild carnivores and, in return, they culled the herd of surplus animals for meat. They also utilised animal parts, such as skins, bones, and horns, for primitive manufacturing. And they may have obtained a renewable harvest of food in the form of milk and blood.

The archaeological site of Tamar Hat, in Algeria, dates from 21,000-17,000 years ago, and more than 90% of the identifiable bones are those of barberry sheep. This strongly suggests that the culling of controlled herds was the primary source of meat, and it gives a clear indication of when herding was already in progress. Herding is at least twice as old as agriculture, and animal domestication is at least twice as old as plant domestication.

Long before the development of agriculture, herders occupied vast areas of natural grasslands in Africa and Eurasia. This was probably the time that people first began to change the face of the earth. Herders traditionally set fire to old grass, at the end of a hot, dry season. They do this to improve the next season's grazing. Most wild grasses have evolved to survive fire, and burning both encourages the growth of new grass, and it destroys many weeds and young trees. Grass fires can extend for hundreds of miles. These herders probably set fire to forests also, in order to extend the natural grasslands.

Mountain Laplanders in Scandinavia, with their reindeer, and the Masai in East Africa, with their cattle, are examples of surviving herder societies. There are also many surviving pastoral societies which use herding as just one component of a more

complex society. Modern cattle, sheep, and goats were originally domesticated by herders, although pigs and poultry were domesticated at a later date by sedentary farmers.

Two other species of animal were domesticated for purposes other than food. The first of these was the dog. Wild dogs and wild people probably began to cooperate, simply by following each other around, at a very early date, and long before the start of herding. The wild dogs had the advantages of speed, and highly developed senses of smell and hearing. The wild people had the advantages of tools, language, superior daylight vision, and intelligence. Dogs were also very useful as watch dogs.

As the association grew closer, the dogs would become totally dependent on the people, who would gradually domesticate them. The process of domestication was probably unconscious, and it involved little more than killing the obstreperous or otherwise useless animals, and both keeping and breeding the most useful individuals. After all, this is exactly what we do today, although some modern dog breeders have curious ideas as to what constitutes usefulness.

Compared with the domestication of dogs, and the first herding, the domestication of the horse was relatively recent. It was domesticated, almost certainly, by herders in the steppes of Central Asia. American cowboys know the value of the horse when controlling cattle, and ancient herders had probably made the same discovery. The horse was also very useful in war and, until the twentieth century, cavalry always had a powerful advantage over infantry, particularly in open plains. Later, the horse was linked to the wheel, first for war chariots and, eventually, for domestic carts and carriages, as well as for ploughs and harrows.

Other animal domestication included cats, for the control of rats and mice, which were always a scourge of people who stored food, and poultry for the production of both meat and eggs.

Animal domestication was much less important in the New World. The people of Meso-America domesticated dogs, the turkey, and guinea pigs, and the people of South America domesticated the llama, and its relatives, for wool and as beasts of burden.

A very recent development has been the domestication of special rats and mice for scientific and medical research. A wide range of special strains is now available to researchers. Equally recent is the domestication of a few species, such as mink and chinchilla, for their fur.

The Domestication of Plants

The development of crop husbandry probably started quite slowly, about ten thousand years ago. Hunter-gatherers discovered that their desirable, food-producing plants had to compete with other, undesirable plants. If the undesirable plants, the weeds, were removed, the food plants flourished. There is little doubt that weeding was the first step in the unfolding of crop cultivation.

Later, these nascent farmers discovered that, by sowing seeds of the desirable plants, they increased the total amount of their food. Later still, they discovered that they could choose *which* seeds to sow. If they sowed only seeds taken from high yielding plants, and from high quality plants, both the yield and the quality of the crop product improved. This was the point at which plant domestication started. It was also the point at which agriculture and, hence, civilisation dawned.

Domesticated plants yield far more than wild plants. They also yield a better quality product than wild plants. And cultivation ensures that only the desirable,

domesticated plants can grow, while the undesirable, competing plants, the weeds, are eliminated. In addition to sowing, these early farmers quite quickly developed many other agricultural techniques, such as tilling and manuring the soil, irrigation, crop rotation, harvesting, threshing, and storing.

Only one species of plant was domesticated in both the New and the Old Worlds. This was a tropical plant, the bottle gourd, which is a member of the cucumber family. The fruit must have been invaluable to primitive people, particularly before the discovery of pottery, because it can be dried and used as a bottle. The species evolved in Africa but the fruit can survive floating in sea water for periods long enough to enable it to cross the Atlantic unaided. It consequently reached the New World without any assistance from people.

Prior to the discovery of pottery, the only means of carrying, fermenting, and storing liquids was in animal horns and skins, sea shells, coconut shells, water-tight baskets, carved wooden bowls, , and bottle gourds. In South America, they also had calabashes. It is thus possible that calabashes and the bottle gourd represent some of the oldest plant domestications of all, pre-dating the use of pottery. Unfortunately, calabashes and gourds are perishable, and their remains do not often survive, in the way that pottery shards survive, to provide archaeologists with information. The earliest archaeological remains of bottle gourds have been found in Egypt in strata dating from 3500 BC, and in Mexico in horizons dating from 7000-5500 BC. Calabashes have been found in archaeological sites in Peru. One of the principle archaeological differences between the New and Old Worlds is that ancient civilisations in the New World were mainly tropical, while those in the Old World were mainly temperate. And calabashes and gourds are tropical plants.

There are two other kinds of crop that were domesticated in both the Old and the New Worlds. These were cotton (Chapter 16) and yams (Chapter 3) which are

indigenous in both hemispheres. However, different species of each crop were domesticated in each hemisphere.

The general results of plant domestication, and crop cultivation, were the production of more food, and better food. This relatively simple step increased the carrying capacity of the human environment by an unprecedented amount, and it probably represents the largest single increase in this carrying capacity during the whole of human cultural development.

Domestication of Micro-Organisms

Micro-organisms have been unknowingly used by people ever since the first fermentation of beer and wine, the first leavening of bread, and the first making of cheese and yogurt. However, it is doubtful if any of these micro-organisms were domesticated, in the sense of being changed genetically by artificial selection. Their domestication consisted of no more than the recognition and culture of special strains. Many cheeses, for example, are fermented with *Penicillium*, the fungus that also produces the antibiotic penicillin. The principle cheese making species of this fungus are *Penicillium camemberti* and *Penicillium rocqueforti*. Similarly, after the discovery of penicillin, new strains of the *Penicillium* fungus were discovered that produced large amounts of this antibiotic. These strains would also tolerate a manufacturing technique known as continuous culture. As a consequence, soon after World War II, penicillin became cheaper than the bottles it was packed in.

Much more recently, micro-organisms have been genetically engineered to produce complex pharmaceutical products, such as human hormones, which cannot be manufactured any other way. And, in the final chapter of this book, some future possibilities arising from the genetic engineering of micro-organisms are discussed. These could lead to further increases in the carrying capacity of our environment.

Adverse Domestication

There is another aspect of unconscious domestication that remains largely unknown to this day. This was the inadvertent domestication of pests, to their advantage, and to our disadvantage. Unconscious domestication can obviously occur in two directions, and this adverse domestication has had a profound effect on human cultural development.

The most obvious pests in this regard are the agricultural weeds, and their evolution occurred mainly in the Old World. The evolution of weeds was the result of an indirect, and unintended, artificial selection. The weeds evolved to exploit the artificial ecosystems created by people in agricultural fields. In other words, they evolved to exploit land that had been disturbed by agriculture. Some weeds, for example, could survive mowing, and they became a major nuisance in hay fields and pastures. These include thistles, buttercups, dandelions, and plantains. Others would survive because their seeds would be difficult to separate from crop seeds, and they would be sown when the crop was sown. Poppies in wheat fields were a typical example, before the days of modern seed cleaning machinery and herbicides.

If all agriculture were to stop, the world population of many species of weeds would decline dramatically, and those species that survived would do so by reverting to their original, pre-agricultural forms. In other words, our ancestors inadvertently domesticated many unwanted plant species into direct competitors, and very serious competitors at that. Weeds have been seriously reducing agricultural yields, and grievously increasing the labour of agriculture, for millennia. The total cost of weeds in the whole history of agriculture is huge beyond computation. And it is only quite recently, with modern herbicides, that farmers have begun to win out against these competitors. Indeed, this is one of the more important of the new techniques that have

enabled us to produce such a large increase in world food production during the twentieth century (Chapter 1).

Crop husbandry in the New World is slightly younger than in the Old World and, traditionally, it involved cultivation practices that were much closer to nature. There were no ploughs, for example. Consequently, the inadvertent domestication of weeds in the New World was considerably less advanced than that of the Old World. Furthermore, much of the New World was not cultivated at all when Europeans first arrived. This was particularly true of the temperate areas which, on the whole, the invading Europeans, and their weeds, preferred.

As a consequence, when Europeans introduced their crops, their weeds, and their cultivation methods, to what was largely virgin land, it was the Old World weeds that dominated New World agriculture. Most of the worst weeds in the Americas originated in Europe. This situation is true also of Australia, New Zealand, and the temperate areas of Africa. Conversely, there are very few New World weeds that are serious in the Old World. One obvious exception to this general rule was the Mexican prickly pear cactus in Australia. However, this was a somewhat artificial situation which was corrected once the parasites of the cactus were also taken to Australia.

A similar, indirect, adverse domestication has undoubtedly occurred with various animal pests, such as rats, mice, and cockroaches. A classic example concerns the clothes moth. This insect is very rare, and very obscure, in a wild ecosystem because it occupies a quite unimportant niche. Its larvae feed on the discarded tufts of wool of wild sheep. Like all mammalian hair, this wool cannot be digested by any organism, other than very slowly by a few species of bacteria. And these bacteria occur in the gut of the clothes moth larvae.

Once wool cloth and clothing became common, the clothes moth began to exploit an entirely new and artificial environment. Its population then exploded into a major nuisance. Woollen clothing had to be carefully protected with moth balls or, more traditionally, in camphor-wood or cedar chests, if it was not to be ruined. This was the origin of the phrase "moth-eaten", in spite of the fact that it is the larvae, not the adult moths, that do the eating. It was only when wool began to be blended with modern synthetic fibres, which the digestive systems of the moth grubs cannot tolerate, that this pest began to decline. These days, clothes moths have largely disappeared, but they can occasionally reappear and ruin a garment made of pure wool.

Unconscious Extermination

In the process of overcoming the hunger compulsion, resulting from those three brutal laws of nature, both our forebears, and our own generation, have succeeded in exterminating other species entirely. We have invariably done this unintentionally. Indeed, when attempting to eliminate another species deliberately, we have succeeded only once, with the smallpox pathogen. And we are very close to the deliberate, total extermination of the leprosy pathogen also. But concerted efforts to eliminate other human diseases, such as malaria, have failed dismally. And, much as we might like to exterminate many pests and diseases of people, domestic animals, and crops, we are unable to do so. Think of houseflies, dog fleas, and rose aphids.

The most obvious of our unintentional extinctions were those that resulted from over-hunting. In East Africa, there are fossils of various extinct animals, such as a giant sheep, that made excellent prey for hominid hunters. Perhaps the most famous extinction was that of the so-called Irish Elk, which was really a moose, that occurred all over Eurasia, and was excellent prey. This animal had antlers with a span of up to

twelve feet, and it became extinct in pre-historic times. But its fossils are still found occasionally, particularly in Irish bogs. Hence its quite inappropriate name.

In North America, the Clovis point people flourished for a thousand years, using their beautiful stone spear points to hunt large animals. At the end of this period there were no large animals left, and the Clovis point culture disappeared.

This disappearance of the Clovis point culture coincides with the mass extinction of some thirty genera of large mammals in North America. These included the mastodon, mammoth, giant sloth, sabre-toothed tiger, and many species of camel. It was all the *big* animals. Similar extinctions occurred in other parts of the world. Thus two genera of kangaroo, a large flightless bird, and various wombats disappeared from Australia soon after the first humans arrived there some 20-40,000 years ago. We cannot be certain that they disappeared because of human hunting, but there is no other explanation, and this explanation is a good one. Certainly, there is no evidence of any geological or climatic changes violent enough to explain these extinctions. More recent examples are the extinction of the Moa birds of New Zealand, and the carrier pigeon of North America.

Plant gatherers also gathered some species of plants to extinction. Quite often, when farming and hunter-gathering continued side by side, a wild plant species would be gathered to extinction while its cultivated forms would survive in the hands of the farmers. Farmers always preserve seed for their next crop with the greatest of care and, when there are thousands of farmers, the chances of a cultivated species of plant being lost are remote indeed. Food gatherers, on the other hand, depend on a wild ecosystem. If a valued wild species is becoming rare, it will be searched out all the more eagerly. Eventually, there will be none left. Crops whose wild progenitors have apparently been gathered to extinction include chillies, peanuts, garlic, ginger, and tea.

However, it would be unjust to suggest that hunter-gatherers are always uncaring of their environment. In surviving hunter-gatherer societies, great care is usually taken to ensure the survival of valuable wild plants, and to ensure that they are not over-gathered, to the point of their reduction or total destruction. But hunter-gatherers can suffer famines and, like farmers who eat their seed supplies only in the very worst of famines, they too can become desperate, and gather plants to extinction.

There has also been an extinction of various carnivores, mainly because human hunters had reduced their prey to extinction. The sabre toothed tiger in North America is an example. The hunting of dangerous wild animals was also the sport of kings. The ancient Greeks, for example, used to hunt mountain lion. There are no mountain lion left in Greece. The same is true of wild boar in most of Europe.

In more general terms, there has been an incredible destruction of wild ecosystems as land was cleared for agriculture. And, in more recent times, there have been many inadvertent extinctions due to pollution of lakes and rivers with industrial chemicals, and acid rain. Other species have been adversely affected, often to the point of extinction, by crop protection chemicals. These are just some of the costs of the world over-population problem, and the world food problem. After all, if the human species increases the carrying capacity of its environment by one thousand times, many ecosystems are bound to change, very profoundly, and other species are bound to suffer.

At first sight, there appears to be no amelioration of this destruction because we are still exterminating other species at a savage rate. But, in fact, there has been a lot of progress, because we are now finally aware of the importance of this problem. This awareness is something new, and humans have an almost infinite capacity to

adjust. It is to be hoped that proper adjustments will be made before too much further damage has occurred.

Ecological Chaos

When an ecologist studies history, he cannot fail to be impressed by the ecological upheavals that people have caused. Quite apart from the extinctions already described, transferring animals and plants from one part of the world to another can cause ecological chaos. Rabbits and the prickly pear cactus in Australia are possibly the two best known examples. Killer bees in the New World, and the Colorado beetle of potatoes in Europe, are two recent examples involving insects.

The first ecological chaos started with animal extinctions from excessive hunting. The extinction of even one species can produce ecological reverberations. For example, with the extinction of the woolly mammoth in America by the Clovis point people, certain carnivores also became extinct, probably because of a lack of prey. Other herbivores then multiplied to population densities far higher than normal. The American buffalo is a typical example. It was possibly close to extinction itself when the Clovis culture ended but, with the disappearance of its predators, it numbers increased dramatically. When modern Europeans first arrived in the Great Plains, these animals numbered about sixty million. Because of the appalling efficiency of firearms, they were hunted almost to extinction. One hunter, called William Cody, so enjoyed slaughtering buffalo, for the sheer love of killing, that he was called “Buffalo Bill”. Modern environmentalists tend to deplore the subsequent decline in buffalo numbers, but it must also be remembered that those numbers were perhaps artificially high, because of the earlier disappearance of their natural predators. The buffalo were originally hunted by indigenous Amerindians, of course, but apparently insufficiently to keep their numbers down.

These ecological changes often produce secondary and tertiary changes in a long series of ecological reverberations. For example, the abnormal herds of buffalo probably destroyed a lot of forest, simply by grazing young tree seedlings. The forest could not regenerate and eventually all the old trees would die, and be replaced with grass. It is entirely possible that much of the natural grasslands of North America were not natural at all.

Some of the worst ecological chaos occurred from over-grazing by herders. Some areas became deserts, such as parts of the Sahara, which were once grasslands. These fragile ecosystems were ruined by over-grazing and, once the soil began to blow, and to separate into dust storms, sand dunes, gravel beds, and bare rock, the damage was irreversible. Other deserts, such as the Kalahari and the Gobi, were once fragile grasslands also, and they might have survived as grasslands to this day, had they not been triggered into soil separation by over-grazing.

It can be argued that, for every species that exists today, many hundreds have become extinct, during the long course of Darwinian evolution. Occasionally, there have been some really massive extinctions, such as the great Permian extinction when ninety percent of all species disappeared. The extinction of the dinosaurs was another. Extinction is a normal component of the process of evolution, and the death of species is as necessary to this process as is the death of individuals.

Unfortunately, the extinctions we are causing now are not normal. In the broad picture of the whole of evolution, they may not matter very much. But they are irreversible, and our descendants may come to regret them immensely. We are all one planet, one ecosystem, one Gaia. “Ask not for whom the bell tolls...”

A brief history of plant breeding

Modern plant breeders have four broad objectives when they attempt to improve our crop varieties. They try to increase the yield, the quality of the crop product, the agronomic suitability of the variety, and its resistance to various pests and diseases. In general, the breeders have been remarkably successful in the first three of these objectives. But they have been much less successful in their breeding for resistance to pests and diseases. I have explained this situation in another book[*] and have no wish to repeat it here. However, a brief reiteration is essential if readers who are new to this subject are to make sense of the present book.

Most plant breeders tend to belong quite firmly to only one of two schools of thought. Pedigree breeders are in love with Mendel's laws of inheritance, and they like to work with single-gene characters. These are characters that either present or absent, with no intermediates. Population breeders, on the other hand, like to work with many-gene characters. These are characters that are continuously variable between a minimum and a maximum.

Ever since the recognition of Mendel's laws of inheritance in 1900, plant breeding has been dominated by pedigree breeders and the use of single-gene characters. Towards the end of the twentieth century, this trend was strengthened by the development of molecular biology. Genetic engineers must, of necessity, work with single-gene characters. There are two kinds of resistance to crop pests and diseases, and their inheritance is controlled by single genes and many genes respectively.

Collectively, the various pests and diseases of plants can be called parasites. For purely technical reasons, the single-gene resistances are called vertical resistance,

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and the many-gene resistances are called horizontal resistance. The pedigree breeders love vertical resistance because it is controlled by single genes. Vertical resistance has several quite considerable advantages. It is so scientifically elegant, and it is so easy to observe and to manipulate in a breeding program that it is immediately attractive to plant breeders. Indeed, this elegance was largely responsible for the classic, gene-transfer breeding of the twentieth century. Vertical resistance also has the very considerable practical advantage that it normally confers a complete protection against the parasite in question. This kind of resistance also has a wide climatic adaptation. This means that a vertical resistance is relatively insensitive to climate, and it is ideally suited to a large central breeding institute that is required to produce cultivars for a large area of cultivation. In this sense, it was the perfect resistance for the 'green revolution' in wheat and rice, as it allowed a single cultivar to be cultivated over a large area. These institutes are obviously interested in 'multi-locational' testing, with a view to finding cultivars with a wide climatic adaptation in other characteristics, such as day-length, temperature, and similar requirements. This philosophy has led to a major increase in the usefulness of individual cultivars. But it has led also to a reduction in bio-diversity.

However, vertical resistance has three grave disadvantages. First, the breeders must first find a gene for resistance. This gene is usually referred to as a 'source' of resistance. If a source of resistance cannot be found, for the simple reason that vertical resistance to that parasite does not occur in the crop species in question, the breeding for resistance cannot even begin.

Second, vertical resistance operates against some strains of the parasite but not others. This means that it is temporary resistance, and it is liable to stop functioning when a new and different strain of the parasite appears. An endless repetition of resistance failures has led to a boom and bust cycle of plant breeding which, in its

turn, has discouraged breeding for parasite resistance. Consequently, modern crop varieties tend to be susceptible to many crop parasites, and this is why we now use crop protection chemicals in such large quantities.

The third disadvantage is that the other kind of resistance, the horizontal resistance, tends to be lost during the process of breeding for vertical resistance. For most of the twentieth century, our crops have been losing many-gene resistance to most of their parasites, and this is another reason why we use crop protection chemicals in such large quantities.

Horizontal resistance is quite different from vertical resistance. It is durable resistance, and it occurs in every plant, against every parasite of that plant. Unfortunately, it requires entirely different breeding techniques, and most plant breeders do not like it for this reason. In fact, most of them stubbornly refuse to use it, or even to investigate it. Horizontal resistance differs also in that it is quantitative in its effects, with every degree of difference between a minimum and a maximum. This too makes it less attractive when viewed from the stance of twentieth century plant breeding. In spite of all this, horizontal resistance offers the only real hope we have of reducing, or possibly even eliminating, the use of pesticide chemicals in our crops.

The 'King' of vertical resistance was a professor at the University of Minnesota. His name was E.C. Stakman, and his most famous student was Norman Borlaug, who was responsible for the Green Revolution, of which more in a moment. Stakman was incredibly influential, and he was very well known among crop scientists. Indeed, he became something of a scientific hero, particularly among the wheat scientists. He has had a biography written, called *E.C. Stakman, Statesman of Science*. And, in the Twin Cities of Minnesota-St. Paul, where he worked, he has had various places and things named after him. Which is all somewhat embarrassing,

because it turns out that Stakman did the one thing that is unforgivable in science. He was wrong.

Stakman, more than anyone, was responsible for the breeding of wheat for vertical resistance to its various pests and diseases. He specialised in the study of vertical resistance to a wheat disease called stem rust. His work was entirely accurate, and scientifically correct, as far as it went. But Stakman completely misunderstood the natural function of the vertical resistances that he was working with, and he completely misused them in agriculture. Nor did Stakman ever appreciate the significance of horizontal resistance.

To this day, it is the wheat scientists who are the bastion of vertical resistance thinking, and who are vociferous in their opposition to horizontal resistance. And, because wheat is such an important crop, which attracts the lion's share of research funds, most other crop scientists have tended to copy the wheat researchers. And the end result of all this is that we pollute our environment, quite unjustifiably, by pumping billions of dollars worth of pesticide chemicals on to our crops each year. We could probably avoid the use of these chemicals almost entirely by the proper utilisation of horizontal resistance.

A further source of opposition to horizontal resistance comes from the molecular biologists who necessarily work with single genes. If they want to genetically engineer resistant cultivars, they must work with single-gene resistances which will normally confer temporary resistance.

Chapter Three

The Agro-Ecosystem

The Quality of the Environment

Many believe that both the beginnings of civilisation, and its subsequent development, depended on the quality of the people concerned, and their innate intelligence, originality, drive, vigour, and skills. In particular, prejudiced folk tend to look at industrially backward peoples in other parts of the world, and to describe them as genetically and racially inferior. These prejudiced folk, of course, are wrong. The development of any civilisation depends entirely on the quality of the environment, and it has little or nothing to do with the ethnic group of humans who happen to inhabit that environment. The differences between the many environments inhabited by people are both major and crucial, while the differences between the ethnic groups are trivial and unimportant.

There were many environmental factors involved in the growth of civilisation, but one stands out far above the rest in its importance. This is quite simply the question of whether or not the environment in question was carrying any wild plants that were suitable for domestication. Moreover, those wild plants had to have the potential to become a major staple.

Staples

When a crop product is important in the nutrition of people, we call it a staple food. For the purposes of this account, it is useful to make a clear distinction between major and minor staples.

A minor staple is one supports a primitive system of agriculture, and allows civilisation to develop as far as the village level. However, in such a village, virtually everyone is engaged in agriculture and food production. The agricultural productivity is not high enough to liberate a significant number of individuals for other purposes, such as the arts, sciences, industry, trade, and cultural improvement generally.

A major staple, on the other hand, is a cultivated species of plant that permits the development of a civilisation. That is, it is sufficiently productive to liberate a significant number of people from food procurement, and to support the growth of cities. Such a major staple must be a domesticated food plant that has eight crucial properties. These properties are those of:

- being easily cultivated,
- producing a new harvest each season,
- being very reliable from one season to the next,
- being highly productive in terms of the amount food produced per acre,
- providing a good return of food per person-hour of labour,
- being very nutritious,
- being easily cooked, and
- producing a food product that can be stored.

There are several hundred thousand species of plants in the world and, incredible though it may seem, only *three* of them, worldwide, have proved suitable for domestication into major staples. These plants are all members of the grass family (*Gramineae*), and they are the cereals called wheat, rice, and maize. Without exception, every one of the great civilisations was founded on one of these three cereals, and any area that had none of them failed to produce a civilisation.

It was the occurrence of these wild species of grass that permitted the growth of the original civilisations and, without these grasses, those civilisations could never have developed. Or they would have developed only much later, more slowly, and to a lesser extent, with a major staple borrowed from another region.

However, the impetus to domesticate plants was an entirely separate phenomenon. This impetus came from the pressure of population. Some ten thousand years ago, with the ending of the ice-age, world climate improved, and the human population began to increase accordingly. All the land areas of the world, which were both habitable and discoverable, became fully occupied. Surplus people could no longer migrate to a new area when their population growth exceeded the critical density. Once again, the population had increased to the limits of the carrying capacity of the environment. Only this time, and for the first time, the human environment involved the entire world. The living-space could be increased no further. If larger populations were to survive, they could do so only by increasing the carrying capacity of their existing environment. And this meant agriculture, which now became possible, with the improved climate that followed the ice age.

Ecotypes

The main theme of this book is that the development of civilisation depends on the environment, and not on the quality of the people who happen to inhabit that environment. To substantiate this view, it is necessary to examine both the differences between environments, and the differences between the people who inhabited those environments. And we must do this both in areas which did produce a civilisation, and those which did not.

The differences in the environments are qualitative and crucial. As we have seen, the precursors of wheat, rice, and maize either did, or did not, occur in a

particular environment. If one of them occurred, increased population densities would permit a civilisation to develop, and cities would grow. If none of them occurred, significant civilisation could not develop, and no cities appeared.

The differences in the people, however, are quantitative, and unimportant. This is a controversial point that we must now examine with some care. In order to do so, we must make a clear distinction between macro-evolution and micro-evolution.

We must recognise that Darwinian evolution consists of both macro-evolution and micro-evolution (Greek: macro = big, micro = small).

Macro-evolution has five characteristics:

- It requires periods of geological time, usually measured in millions of years;
- it produces changes that are new, resulting from new genetic code;
- these changes are irreversible and macro-evolution never goes backwards;
- it produces new species;
- and, macro-evolution leads to an increase in the complexity of living organisms.

Micro-evolution is the converse in all five of these characteristics.

- It is relatively fast, requiring periods of historical time only;
- it produces changes that are not the result of new genetic code;
- it produces changes that are reversible;

- it does not produce new species, but it does produce subdivisions of a species called ecotypes;
- and, it leads to a re-arrangement of existing complexity, rather than the production of an increased complexity.

Domestication is micro-evolution, not macro-evolution, and it differs from natural micro-evolution only in that it results from artificial selection pressures. Natural micro-evolution does not produce new species, but it does produce subdivisions of a species called *ecotypes*.

An ecotype is defined by differences within one species within one ecosystem. Selection pressures vary from one part of an ecosystem to another, and different selection pressures produce different ecotypes. The classic example was the two ecotypes of one species of plant on a mountain. One ecotype grew at the top of the mountain, and was short, with thick, wind-resistant stems and leaves. The other grew at the bottom of the mountain where there was little wind, and it was tall, with lush stems and leaves. There were all degrees of difference between these two ecotypes, depending on how high up the mountain they were. When each of the extreme ecotypes was put in the environment of the other, it changed, in the course of a few generations, into the form best suited to that environment. In other words, it responded to selection pressures for either wind-resistance at the top of the mountain, or competition with other tall plants, at the bottom.

There is an even more striking case of changing ecotypes called industrial melanism. This involves some seventy different species of moth that have superb camouflage colouring to protect them from insect-eating birds, when they are at rest on the bark of trees. With the atmospheric pollution that occurred during the industrial revolution in Britain, the bark in many towns turned black from the soot in

the air. Moths that were camouflaged for light coloured bark were very conspicuous on the black bark and, in all of these seventy species, new ecotypes soon appeared, in which the moths were black. It was shown by breeding experiments and differential selection, that it was quite easy to change black moths to light-coloured moths, and *vice versa*, in a few generations.

The so-called human "races" are no more than different ecotypes. It is likely that our loss of body hair was accompanied by a pigmentation of the skin. This is a feature that does not occur in any other primate. Except for exposed skin in the face and hands, chimpanzees, gorillas, and baboons all have white skins which are protected from sunburn by body hair. It is probable, therefore, that all the original humans had skins that were both hairy and white. It is also probable that, when our remote ancestors lost their hair, their skin turned dark. The skin that was both white and hairless apparently evolved only later, when some of our ancestors migrated out of the tropics, and into the temperate regions where the dangers of sunburn were less acute, and a dark skin interfered with the production of Vitamin D by sunlight. The key point here is that it was these light skinned people who migrated back into the tropics in Southeast Asia, and then, once again, micro-evolved the dark skins of the Melanesians and the Australian Aborigines.

I was once in Papua New Guinea, which is equatorial, and where the indigenous people date from at least forty thousand years ago. They have dark skins, fuzzy hair, and thick lips. At first sight, they are indistinguishable from Africans. But, having lived for many years in Africa, I was able to recognise an East African instantly, when I saw him in a group of Papua New Guineans. He too had dark skin, fuzzy hair, and thick lips. But I was so confident of my identification that I greeted him in Swahili, and he almost wept at hearing his home language in such a far-away place. This story, unimportant in itself, drove home to me very forcibly that the

visible differences between human ethnic groups are not new, they are reversible, and they can occur in periods of historical time or, at least, sub-geological time. Furthermore, this micro-evolution does not lead to new species. It leads to changing ecotypes. We humans are all one species, and the differences between our ecotypes are quantitative, reversible, short-term, and unimportant.

As we have seen, any normal human child, born anywhere in the world can learn any human language. Equally, a member of any human ecotype can be sexually attractive to a member of any other ecotype, and they can have children without any suggestion of hybridisation or infertility problems. And most of the ecotype traits of those children will be quantitatively variable, and will be about halfway between those of each parent. In other words, it is impossible to define a human "race". We can merely say of certain individuals that they represent an extreme of variation in certain variable characteristics. And this variation is trivial when it comes to the growth of cities.

After all, the Amerindians of Central America, the natives of Europe, and people of the Far East are usually described as different "races", often designated, quite disgracefully, in terms of the colours red, white and yellow. Each of these human ecotypes lived in an environment where a wild plant could be domesticated into one of the major staples called maize, wheat, and rice, respectively. Each of these human ecotypes also produced cities.

Other human ecotypes, in other environments, had no wild plant suitable for domestication into a major staple, and they did not produce cities. It was the environments that were significantly different, not the people.

It is also worth noting some quantitative differences. There were a number of environments, inhabited by distinct human ecotypes, who domesticated minor staples, and developed an agriculture that was just short of supporting the growth of cities.

These human ecotypes were as far apart, and in environments as different as, equatorial Africa, the high Andes, and Papua New Guinea. And, these human ecotypes domesticated minor staples as different as sorghum, potatoes, and taro. On the same basis, a number of distinct human ecotypes had much earlier, and independently, developed into herders. This happened in Africa, Asia, and northern Scandinavia, with different species being herded in each area.

Agriculture

Agriculture was the technical breakthrough that produced a massive increase in the carrying capacity of the human environment. It also allowed specialisation among people. In hunting gathering societies, the principle activity of every adult is the procurement of food, usually with the men doing the hunting, and the women doing the gathering. Agriculture, on the other hand, is so much more productive that only a portion of the adult population need be involved in food procurement. The remaining adults can then be spared for other activities such as the arts and sciences, teaching, medicine, law, trade, building, manufacture, religion, government, and even war. Obviously, this specialisation permits a much more rapid growth of culture.

There is a popular misconception, that has been carried uncritically from textbook to textbook, to the effect that hunter-gatherers have more leisure and, hence, a better quality of life, than agriculturists. This, of course, is nonsense. In a civilised society, farm labourers are usually the lowest paid workers and, regrettably, they have to work hard and long to earn a decent wage. If we compare hunter-gatherers exclusively to farm labourers, then the hunter-gatherers undoubtedly have more leisure. But this is a meaningless comparison and, when considering quality of life, we must take two other factors into account. First, we must compare hunter-gatherers to the agricultural population as a whole. On this basis, the hunter-gatherers spend far

more of their total time on food procurement than do the agriculturists, many of whom are freed entirely from this work. Second, we must consider qualities other than mere leisure, such as living in houses that are permanent, warm, and dry; the availability of education; the opportunity to improve one's lot; the benefits of medical and scientific research; and so on.

Agriculture is clearly much more productive than a wild ecosystem. Indeed, agriculture can be defined as an artificially controlled ecosystem, in which biological activity that is of value to the farmer is encouraged, while biological activity that is harmful to the farmer is discouraged. We can even speak of the *agro-ecosystem*.

Since its first appearance, the productivity of agriculture, and the carrying capacity of the human environment, have been greatly increased by two kinds of development. The first was a series of technical improvements, such as the invention of the plough, and the use of irrigation. This series of improvements culminated in very recent, modern advances which include mechanisation, scientific plant breeding, the use of artificial fertilisers, and the development of chemical pesticides. The best crop yields are now about ten times greater than those of a century ago, even if the desirability of some of these modern techniques, such as chemical pesticides, is debatable.

The second development was possibly even more important, and it was the redistribution of crop species around the world. This redistribution began with the Austronesians (Chapter 9), and it accelerated rapidly after the European explorations of the late fifteenth century. The effect on agriculture, and the overall human population density, was dramatic. Walk on to any farm, anywhere in the world, and check what crops the farmer is growing. The chances are that his crops are of exotic origin. That is, they are foreign species which originated somewhere far away and, quite possibly, on a different continent.

Farmers often talk of the "Irish" potato but it originated in South America. In the United States, there is a huge wheat belt, and an even larger corn belt. The wheat originated in the Middle East, and the corn (maize) originated in Mexico. And the soya of the soya belt originated in China. In fact, the only crops which originated in the United States are sunflowers and the Jerusalem artichoke. Even Kentucky blue grass came from Europe.

In much of the South Pacific, the staple food is sweet potato which originated in South America. In much of Africa, the staple foods are beans and maize, which both originated in Central America. The coffee of the New World originated in Africa. The rubber of Malaysia comes from Brazil. Sugarcane came from New Guinea. Tomatoes and pineapples came from South America, and apples came from Iran. Grapes came from Central Asia. Ginger and black pepper originated in India, while red peppers came from Mexico. Nothing of any importance originated in either Britain or Canada.

The north-south distribution of plants is governed by climate. Tropical plants cannot survive a winter, and temperate plants do not normally thrive in the tropics. But the east-west distribution of plants is governed by oceans, and the time of formation of those oceans. The Atlantic and Indian Oceans first appeared about sixty five million years ago, with the beginnings of the most recent phase of continental drift.

Plant species which evolved before this separation, such as ferns and mosses, occur equally in all the continents, other than the ice-covered Antarctic. But species which evolved after this separation, such as most of the flowering plants, are confined to only one continent, except for a few species which had seed dispersal mechanisms capable of crossing an ocean in fruit that floats, such as coconut (Chapter 8), cotton (Chapter 16), and the bottle gourd (Chapter 2).

This natural distribution of plants had two major impacts on human history. The first was the fact that ancient peoples could only domesticate the species which they had to hand, and this meant that very different species were domesticated in various parts of the world. The second was that, more recently, when people learnt how to explore the entire world, they artificially redistributed these very different species throughout the world. It was the original distribution of wild plants, *and nothing else*, that determined whether or not a civilisation could develop, and when, and where.

The Dates of Agriculture

In the time scale used by geologists and evolutionists, the various independent discoveries of agriculture happened simultaneously all over the world. The few centuries difference in the actual dates of domestication of wheat, rice, and maize are insignificant in terms of the evolutionary history of humankind.

The many human populations of the world apparently all reached the limits of the natural carrying capacity of their environments within a few thousand years, during the period 10,000-5,000 BC. This period also saw the end of the last ice age, with corresponding improvements in climate. The world not only became warmer. Secondary effects included a greatly increased habitable area that had been previously covered in ice, and was now covered in plants. There was also an improved rainfall, and many deserts also developed plant life, and the complex ecosystems that go with it.

The improved climate probably had two, mutually reinforcing effects on people. The human populations increased, requiring a greater supply of food, and the environment itself became more conducive to agriculture. Any further increases in total human numbers were then possible only by increasing the carrying capacity of

that environment. That increase was possible only with agriculture which, in its turn, was possible only with the improved climate. This explains why all the great civilisations emerged at the same time, when measured in the total evolutionary time scale of three and a half billion years, or even when measured in the total history of human culture, which is about two million years.

Ease of Cultivation

If we had to dig four feet down in order to harvest potatoes, this crop would not be cultivated. And if we had to harvest wheat by picking the grains up from the ground, this crop also would not be cultivated. It is a statement of the obvious that all existing crops are easy to cultivate because, were they not, they would not be cultivated. Indeed, they would never have been domesticated. But this point was not so obvious to early farmers who, no doubt, were trying to cultivate every wild plant that was in any way useful. One crop that is not very easy to cultivate is rice. The building of fields that can be flooded, and the maintaining of those floods, are not the easiest of agricultural methods. However, the productivity of rice is so incredibly high that these difficulties can be tolerated.

Productivity

Productivity means two things. Most obviously, it means the amount of food produced by a crop per unit area of land. And, second, it means the frequency of production. A major staple must produce at least one harvest per year. In the best areas, rice can provide two or even three harvests per year. Gin-seng is an example of a species that requires five years to produce only one harvest. Such a slow crop could never become a major staple. Most tree crops produce a harvest every year, but their seedlings or cuttings often require several years of growth before they produce any

fruit, nuts, or olives. However, the trees that produce Brazil nuts require about eighty years of growth before they produce a harvest.

Reliability

If there is drought, some plants just die. If they are cultivated plants, this means that the entire crop is lost. Such a crop is not reliable, or dependable. Other plants are drought-resistant. If they are cultivated, they provide a much more reliable crop. Plants that lack water do not grow, and they do not produce. But, if they are drought-resistant, they do not die either. And they can begin to grow again, and to produce, when there is new rain.

The same is true of frost. Coffee in Brazil is famous for being periodically damaged by frost, and the world price of coffee then escalates. And there are many crops which farmers in temperate regions dare not plant too early in the spring in case they are spoiled by a late frost. These crops are often grown in greenhouses for this reason.

Yet other crops are susceptible to pests and diseases. In a season that favours the pest or disease, there can be a population explosion which ruins the crop. Varieties that are resistant to pests and diseases are obviously more dependable than those that are susceptible. A special aspect of crop reliability is that the resistance to pests and diseases must be durable. Oddly enough, it was only during the twentieth century that the durability of resistance was lost, and new crop varieties were produced with temporary resistance. This was because of some very poor science, and it is discussed later (Chapter 2). We have actually introduced instability into previously stable crops, such as wheat, beans, rice, and potatoes.

Obviously, any crop that is unreliable cannot become a major staple. Even with reliable crops, there are risks of crop failure because the climate itself is unreliable.

Joseph's seven lean years in biblical Egypt are a case in point. But, if crop failures are at all frequent, the growth of cities is unlikely to occur, and even less likely to be sustained.

Return for Labour

Return for labour differs from productivity in that it involves the number of man-hours of work required to produce one unit of food, compared with the number of units of food produced per unit of land, and per unit of time, discussed above. Obviously, if a crop is so labour-intensive that it requires more than one man-day of work to produce enough food to feed one man for one day, the productivity is too low to justify cultivation. One man could not even feed himself by cultivating such a crop. On the other hand, if one man-day of work can produce enough food to feed one hundred men for one day, the return for labour is good, and many adults will be spared from food procurement to do other things, such as building cities.

Adjuncts of Staples

In each of the regions with a major staple, various other species of plant were also domesticated. These were mere adjuncts of the staples, however, and they did not fulfill the five requirements of a major staple. They were not themselves capable of supporting a civilisation unless the major staple was also present. The adjuncts could do no more than support the major staple, making it even more suitable for the growth of cities.

The most important of the adjuncts were plants that produced protein. These are the so-called grain legumes, or pulses, that are members of the botanical family *Leguminoseae*. In the wheat areas, they were peas (*Pisum sativum*), broad, or field, beans (*Vicia faba*), and lentils (*Lens esculentum*). In the maize areas, they were

haricot beans (*Phaseolus vulgaris*), and other species of this genus. In the rice areas, they were soya (*Glycine max*), and various other species. Other adjuncts included minor cereals, such as barley, millets, and sorghum, as well as many fruits and vegetables. Some plants were domesticated for purposes other than food. These other uses included fibres, oil, drugs, beverages, and perfumes.

Minor Staples and Minor Civilisations

A few species of plant were domesticated into staples of moderate importance, and they permitted modest civilisations to develop. Usually, these minor civilisations never developed beyond large villages, and they usually had little in the way of cultural developments, such as writing, mathematics, building in stone, or metal working.

For example, potatoes in South America could be frozen at high altitude, and then dried in the sun. They could then be stored, and they became a minor staple. The Inca empire was ruled by people from these potato areas, but the conquered, low altitude peoples of the Inca empire, and their superior civilisation, had all originated with the cultivation of maize.

Although the ruins of Zimbabwe do not constitute a major civilisation, they do represent the only important, indigenous, stone buildings in Africa South of the Sahara. These beautiful ruins, built of uncut stone with mortarless walls, pre-date the Portuguese introduction of maize, sweet potatoes, and cassava from the New World. We know little about the people who built them and, because of their climate, these people presumably depended on sorghum and millets as their staples.

By way of contrast, in the tropical rain forests of West Africa, food storage is unnecessary because there is no dry season and no winter. Yams (*Dioscorea rotundata*) cannot be stored, but they can be harvested at any time of the year, and the

area known as the 'yam belt' accordingly produced a simple, indigenous civilisation of large villages, famous mainly for their beautiful art work, including the lost-wax process of casting metal.

Millets were quite important cereals in China, before the introduction of rice. This was an agricultural society but it was also a primitive one, restricted to small villages. Chinese civilisation did not really blossom until rice became available in the third millennium BC. Rice was a short-day, tropical crop, and considerable acclimatisation was required before it could be grown in northern China.

Papua New Guinea has a very ancient agricultural society, dating from 9,000 years ago. This agriculture was based on the taro crop (*Colocasia esculenta*), but it never developed beyond the small village stage of civilisation. Taro is a labour-intensive crop, having a relatively low yield per man-hour of work. For this reason, it never became a major staple, and it never permitted the growth of an important civilisation.

Barley occasionally replaced wheat, or was of equal importance to it, as the main staple. This was because of its salt tolerance, particularly in the irrigated fields of the ancient civilisations in the Tigris-Euphrates valley, where prolonged irrigation had led to salination of the soil. However, the free-threshing character was never found in barley, and this cereal remains difficult to separate from its husks. To this day, barley is important only for making beer, or as an animal feed, because neither of these uses requires threshed grains. Barley husks can be removed with modern milling machinery to produce 'pearl' barley, used as an additive in soups and stews, but it is of very limited importance as a human food.

Areas Lacking the Major Staples

Any area of the world that lacked wheat, rice, and maize failed to develop a major civilisation. The importance of wheat, rice, and maize becomes obvious if we examine these deprived areas, which include the temperate zones of both North and South America, Africa south of the Sahara, and Australasia.

Temperate North America

When the Pilgrim Fathers arrived in North America, they met indigenous people who were mostly hunter-gatherers. A few of them had a primitive agriculture, but both the crops, such as maize and tobacco, and the techniques of cultivating them, had come from the South. And these crops grew too poorly, and had arrived too recently, for any major civilisation to develop. As one travelled from New England towards the southwest, both the importance of agriculture, based on maize, and the degree of civilisation, increased. However, at the time of the Pilgrim Fathers, these civilisations had not survived a combination of climatic changes, and the population decimation caused by human diseases inadvertently introduced by the Spanish.

Temperate South America

No crops originated in temperate South America, and no agriculture and no civilisation developed there either. We should not overlook the potato which, in a sense, is a temperate crop that was domesticated in the cool, high altitude, but equatorial Andes. It eventually became a crop of major importance all temperate countries (Chapter 11), but it did not reach, or in any way influence, temperate South America until quite recently.

Africa South of the Sahara

In Africa south of the Sahara, hunter-gatherer societies were replaced by cattle herders who were themselves later replaced by agriculturists who, however, lacked the major staples. Their agriculture involved various minor staples such as millets, sorghum, yams, and bananas. These agriculturists were undoubtedly food producers, but they lacked a plant that could become a major staple, capable of supporting a major civilisation. It was not until the Portuguese introduced maize from the New World, as well as beans, sweet potato, and cassava, that a really reliable and productive food supply became available.

The introduction of these New World species transformed the carrying capacity of the African environment. However, that was less than five centuries ago, and this is not a sufficient period for an indigenous culture to develop into an important civilisation, particularly when it is being assailed from outside, by more technically advanced foreigners, who were also bent on stealing people as slaves. There is little doubt, however, that, after the introduction of these New World crops, the population density of Africa south of the Sahara increased considerably. It is doubtful whether the slave trade could have developed as it did, without this African population increase, and without these New World crops in Africa.

Australia

Similarly, in Australia, there were no indigenous plants suitable for domestication. When European agriculturists arrived there, they encountered people who were still in the hunter-gatherer stage of cultural development. It was typical of these invading agriculturists that they regarded the hunter-gatherers as primitive, and genetically inferior. However, these newly arrived Europeans did not succeed in

domesticating any plant that is native to Australia, and all the cultivated plants in Australia today are of foreign origin.

It is worth noting, however, that hunter-gatherers often exhibit artistic abilities of great originality and creativity. The indigenous Australians have a cultural tradition of beautiful rock painting, and it is a tradition that has continued without a break for at least 20,000 years and, possibly, much longer. It is, without question, the oldest continuing culture in the world.

Papua New Guinea

It is noteworthy also that some of the oldest agriculture in the world was in Papua New Guinea and, as we have seen, it dates from 9000 years ago. However, these people were unable to domesticate any plant into a major staple, because no suitable wild plants existed in that area. Their agriculture had no important staples until the Portuguese arrived, less than half a millennium ago, with maize, supported by beans, cassava, and sweet potatoes. As we have seen also, the traditional crop in Papua New Guinea was taro. This root crop requires a lot of labour to produce relatively little food. In this sense, maize is one of the most profitable crops in the world, requiring little labour to produce much food. Sweet potatoes are also very productive. The Portuguese also introduced pigs which transformed the local dietary habits. The big celebrations, for example, were abruptly changed from pudding feasts into roast pork feasts.

Chapter Four

Civilisation

Civilisation Defined

Civilisation may be defined as the growth of cities, and everything that both contributes to, and emanates from, this growth, such as systems of law and order, and the various artisan, industrial, artistic, professional, and intellectual skills. An essential feature of civilisation is that only a small proportion of a large population need be occupied in food production. When a small proportion of the populace is able to supply the entire food requirements of the society, there are many individuals with spare time. All these liberated people can devote themselves to other activities, and they can specialise. Each of them could concentrate on doing only one thing, but doing it very well. It is this specialisation, in government, education, the arts and sciences, religion, and even war, that is characteristic of civilisation.

With the growth of a city, and its large population crowded into a limited space, both a system of law, and a system of government become essential. Various artisans and professionals can develop their spheres of activity only if there was law and order. This is very different from the hunter-gatherer way of life.

Population Density

Once again, the carrying capacity of the environment, and the human population density are crucial factors. The growth of cities depends on a large population, with surplus people available for specialisation. This level of population

density is possible only with agriculture. And it is possible only with certain kinds of agriculture. It is possible only if the agriculture involves one of the three basic staples called wheat, rice, and maize. Then, and *only* then, is it possible for villages to become cities, and for cities to become states.

Hierarchies

One of the first effects of an increased population density is the amount of control that individuals exert over each other, usually in the form of a dominance hierarchy. Dominance hierarchies are common in other species of social mammal, such as chimpanzees, baboons, and wild dogs. But they had largely disappeared with humans, and had been replaced with what biologists call pair bonding. This is just a pompous biological term for love. If parents love each other, and their children, there is no need for domination or control. With good pair bonds between parent and parent, parent and child, and child and child, individuals cooperate rather than compete with each other. This is the basis of altruism. It is also the behaviour that predominates in small bands of hunter-gatherers.

But when populations become large, this system of social organisation, based on pair bonds, is no longer effective. The reason is fairly obvious. Each individual can form only a limited number of bonds and, when the population exceeds that number, there will be unbonded individuals interacting with each other. Altruism and cooperation then stop, and competition, and even confrontation, begin. Unbridled competition leads to every known form of crime, ranging from minor theft, to murder, and wholesale war.

In order to cope with this problem, the human species returned to the decidedly more primitive, and less pleasant, system of social control based on dominance hierarchies. The essential feature of a hierarchy is that the people in one rank

dominate everyone in the lower ranks. People in one rank are also subservient to anyone in a higher rank. Rank and numbers are also related. The more elevated the rank, the fewer the people in it. And the lower the rank, the more the people in it. There is only one king, but there are many serfs. And the serfs had a miserable time of it, always, throughout the whole of history. It would be wrong to blame the system. This was just one of the consequences of a major increase in the carrying capacity of the environment.

All the early cities, and states, were characterised by despotism and tyranny. It is only relatively recently, in the growth of human culture, that there has been a move away from social control by dominance hierarchy. This trend is called democracy. It is slowly becoming clear to everyone that we need democracy in every human group, ranging from the smallest family, to the largest nation, to the world, and to the entire human species, as a single whole.

Religion

A further form of social control developed out of the belief systems called religion. An important aspect of all the great religions was that individuals were persuaded to behave well by both threats of punishment, and promises of reward. Most of the threats and promises were unverifiable, because they referred to one's supposed fate after death. Some of the more oppressive sects also controlled their members by the use of shame, guilt, and fear, during their life. We now recognise that the resulting misery was too high a cost to pay for the enforcement of good behaviour. Fortunately, with improved democracy, law enforcement, and education, these oppressive belief systems are quietly fading into the background of our society.

The Effects of Living in a Fixed Location

There was one special aspect of the change from hunter-gathering to crop husbandry that had a profound effect on the development of human culture. Hunter-gatherers must be constantly on the move, in their search for wild plants and animals to eat. They are nomads. They have no choice in this matter because, if they stayed too long in one place, they would starve. The same is true of the herders of domesticated animals, such as modern Laplanders and their reindeer, or modern Masai and their cattle, who must move both locally, to find daily grazing, and widely, with the changing of the seasons, to find distant areas of good grazing.

Cultivators of crops, on the other hand, are in exactly the opposite situation. They cannot leave the locality of their crops because they must sow, till, weed, and harvest them. They must also store the harvest and, above all, they must guard both the crop, and the store, against wild animals and human marauders. If cultivators left their crops or their stores unguarded for even a day, they would probably lose them, and then *they* would starve. Hunter-gatherers cannot store food in any quantity because most of the products of their hunting and gathering are perishable. Without wheels and roads, there is also a strict limit to the amount of food they can carry from one camping ground to the next.

Even a primitive agriculture leads to a population increase because of the increased food supply. Less obviously, a fixed location with a permanent home base, can also contribute to a population increase, mainly because of a reduction in the death rate. A mother can care for her children much more effectively if they live in a permanent home, which is warm and dry, and which contains a store of food. The mortality among children, as well as among the sick and the infirm, is reduced. Also, farming is less dangerous than hunting, and it has a lower mortality rate. An increased life expectancy leads to an increased reproduction, and a larger population. And a

productive agriculture will feed that larger population. The two processes are mutually reinforcing.

Pottery came into general use with the development of farming and, above all, with a sedentary existence. Pottery is rather heavy, and it is fragile stuff. For this reason, it is not very useful for hunter-gatherers who have to carry all their possessions with them, as they constantly move from place to place. They prefer the much older, and lighter, baskets. But, for people who live permanently in one place, pottery is extremely useful for cooking, for storing both grain and liquids, and for fermenting. It is worth noting, however, that some hunter-gatherers lived in an environment that was so rich in food supplies that they could adopt a sedentary existence, even without agriculture. Such people developed pottery before they developed agriculture. For this reason, the oldest known pottery in the world predates agriculture by several thousand years. It comes from Japan, which had a singularly rich, pre-historic environment.

Perhaps the most conspicuous consequence of living in a fixed location is that people can erect permanent buildings. What would be a temporary shelter for hunter-gatherers, becomes a permanent house for cultivators. What would be a mere camp site for hunter-gatherers, becomes a permanent village for cultivators. Because a large village is stronger and more secure than a small one, and people usually do not want to migrate unless they absolutely have to, there would be a tendency for the size of villages to increase, particularly as agricultural productivity increased. Once the population size increases considerably beyond that of a hunter-gatherer band, entirely new social phenomena begin to appear. It is these phenomena, for better or worse, that constitute civilisation.

Calendars

The necessity of remaining in one place led to important developments in astronomy. Hunter-gatherers and herders were nomads, the world over, and they used a lunar calendar, based on the waxing and waning of the moon. The lunar calendar is thus the oldest by far, and it is so revered and loved that it is still widely used. It is the calendar in Islamic countries, for example, and it was used for millennia in China. It still dominates the Judaic religion, as well as some of the festivals in the Christian religion. Unfortunately, it is also an inaccurate calendar because a year of twelve lunar months is out of phase with the solar year by eleven days. This does not matter very much to hunter-gatherers, but it is of the considerable concern to agriculturists who require accurate timing of various activities ranging from the sowing to the harvesting of their crops. Both farmers and city dwellers must also be able to calculate how many more days a dwindling store of food must last until the next harvest is available.

Nomads were compelled to use a lunar calendar because they were quite incapable of developing a solar calendar. Such a calendar depends absolutely on people remaining in one place. They must measure the exact spot on the horizon where the sun either rises or sets each day. From this, they can determine the summer and winter solstices, and the vernal and autumnal equinoxes, with great accuracy. They can then formulate a solar calendar which is very reliable. It is impossible for hunter-gatherers and cattle herders to remain in one place for long enough to do this. Nor do they need to.

It is noteworthy that solar calendars were developed only by crop cultivators and, it seems, every major crop cultivating society succeeded in developing one. It is probably no accident that Stonehenge, with its astronomical features, was built only after wheat farming had reached Britain. All the original civilisations, in Egypt,

Mesopotamia, the Indus and Yellow River Valleys, and Central America, independently developed solar calendars. And most of them independently, and ingeniously, developed a system for coordinating the lunar calendar with the solar calendar. In its day, the Maya calendar was possibly the most sophisticated of them all, and it was able to measure time in millions of years.

Mathematics

With the growth of a city would come the development of architecture and, for this, a knowledge of mathematics was essential. Mathematics probably developed first with the study of calendars, but architecture required a rather different kind of mathematics, and it led to the development of geometry. Mathematics has often been called the most perfect example of human thought, but necessity is the mother of all invention. Hunter-gatherers had no necessity for mathematics and, to the best of our knowledge, they neither discovered nor needed it. The growth of cities required both calendars and architecture, to say nothing of the simple counting of people and taxes. Every one of the original civilisations discovered mathematics, and developed it according to their needs, independently of all the others.

The original Mesopotamian mathematics was based on the numbers five and twelve, and their product, which is sixty. This is where the dial of modern clocks comes from, with sixty seconds to the minute, sixty minutes to the hour, in twelve subdivisions of five minutes each, and twelve hours of either day or night. The 360 degrees of arc of a circle, derived from sixty times sixty, as well as the degrees of longitude and latitude in mapping the globe, are based on the same concept. These basic figures of five and twelve apparently derive from the most fundamental numbers of all. These are the five fingers of one hand, and the twelve lunar months in one year. It was only much later that the ten fingers of both hands became the basic

number in the decimal system. And, most recently of all, it has been appreciated that the figure eight would make a better basic number. Indeed, this is the basis of the so-called ‘new math’, and it has been used in computers with their eight bits to a byte, etc.

Writing

The essential feature of writing is that it produces a permanent record. Before the development of writing, history was passed down from generation to generation, verbally, as folklore. Equally, great poetry depended on bards to remember it, and to teach it to the next generation. Human memory is fallible, and both the history and the poetry were liable to become corrupted or, worse, forgotten completely. The development of writing thus marks the boundary between pre-history and history.

A dramatic example of this switch comes from the ancient Mayan civilisation which covered most of Guatemala, Belize, and the Yucatan Peninsular in Mexico. Until recently, this civilisation was a pre-historic one because we knew little about it, apart from its huge, and numerous, ruined buildings. Now that its pictographic writing has been deciphered, the study of the Maya has become history, instead of pre-history.

A similar story can be told of ancient Egypt, and the decipherment of its two scripts by Jean François Champillion, from the Rosetta stone, and ancient Egypt became history instead of pre-history. Similarly, the script of the ancient Minoans in Crete, called Linear B, was deciphered by Michael Ventris but, unfortunately, the surviving texts contain little of historical interest. Originally, writing was used almost entirely for making quite banal records of taxes and payments in kind. This is why surviving examples of the Linear B script are uninteresting, because they consist

almost entirely of storekeepers' records. The earlier Linear A script has not been deciphered but it is thought to be more of the same.

Later, as literacy became common, writing was used to make public announcements and memorials, often of king's names and achievements, but also of codes of law. Writing also began to be used for recording poetry, and for diplomacy. Eventually, scholars began to make permanent records of their work, whether it was history, philosophy, medicine, geometry, or geography.

Individual Ownership

With the development of permanent buildings would come the concept of individual ownership and individual wealth. Hunter-gatherers and herders cannot accumulate much in the way of possessions because everything they own must go where they go, and they cannot carry very much. Because they own so little, they have only a rudimentary concept of ownership. But a secure house in a secure village can hold many possessions, including domestic animals and harvested grain. Other possessions would include tools, as well as clothing, furniture, adornments, and cult objects. Also possible, although probably rare at that early stage, was the concept of the individual ownership of land. This is a concept that is incomprehensible to hunter-gatherers who do, however, have a strongly developed sense of communal territory.

Taxation

As the population increased, and the new cities began to grow, the government would became more sophisticated, and taxation would be required, if only to feed the non-producers of food. Originally, before the days of money, taxation took one of

two forms. People could pay their taxes either in non-perishable farm produce, such as grain for the public granaries, or in the form of *corvée* labour.

Corvée Labour

Corvée labour is named after the French statute labour that existed until the revolution in 1776. This kind of labour has also been called involuntary labour and it was usually enforced by the military. It was a very ancient form of taxation which became possible only with the large populations that resulted from agriculture, and with the growth of organised states. It was normally exacted during the agricultural slack season and, no doubt, one of its purposes was to keep idle hands occupied. Nevertheless, it was also very productive and, for the first time, monumental public works, that were not previously possible, began to be constructed.

Ancient Egypt, with its pyramids, provides the classic example of monumental architecture built with *corvée* labour. The largest, and most famous, is the pyramid of Cheops at Giza. It is just one of eighty other Egyptian pyramids. It apparently took twenty years to build, and it contains an estimated two and a half million blocks of stone, each weighing about two and half tons. Originally, it was 481 feet high and its base covers an area of more than thirteen acres. It is built with incredible accuracy in the right angles of its plan, the horizontal alignment of its courses, and its north-south orientation, which is accurate to within one tenth of a degree. Herodotus, who saw it undamaged, considered that the covered causeway that linked it to the river temple probably required as much work as the pyramid itself. Sadly, the entire complex has been used as a quarry for so long that it is now a ruin, although the core of the pyramid itself is largely intact.

Ancient Egypt has a strictly seasonal agriculture which depended on the annual flooding of the Nile for irrigation. Once the harvest was secure, there was little work

for the agriculturists to do, and they were dragooned into this *corvée* labour. In addition to pyramids, this labour was also responsible for building many palaces, tombs, and temples.

China had an almost identical system of *corvée* labour but these people did not build pyramids. Their most famous monumental architecture was probably the Great Wall which was originally completed in 214BC, and was then 450 miles long. This stone and brick, military wall was mostly thirty feet high, and carried a twelve foot wide road along its top. Later, the wall was extended to a total of 1,400 miles. Like the Egyptians, the ancient Chinese also used *corvée* labour to build many palaces, tombs, and temples, including the Forbidden City in Beijing.

Similar monumental architecture was produced by the Mesopotamian civilisations. Their pyramids were known as *ziggurats*, but they too built many palaces, tombs, and temples. The peoples of Central America also built pyramids, palaces, tombs, and temples with *corvée* labour. The most famous are the pyramids of Teotihuacan. After the destruction of the Aztec empire by Cortés, the Catholic Church also used *corvée* labour to build churches in really ridiculous numbers. The small Mexican town of Cholula has the double distinction of having both the largest of the ancient pyramids, as well as three hundred and sixty five churches. One of them is built on top of the ancient pyramid.

Stonehenge was obviously built by *corvée* labour. Some of its huge stones were brought from Wales. Local stones, called *sarsens*, consisting of sandstone, and each weighing some twenty six tons, were eighteen feet in height, and were used to construct the main circle that is a hundred feet in diameter. It has been estimated that 1,500 men would have had to work for ten years merely to transport these stones. No doubt, this work was done in the winter, during the agricultural slack season. Less well known are other Neolithic monuments in western Europe, notably the standing

stones at Carnac, in Brittany, which must have required considerably more labour than Stonehenge.

A similar recruitment of involuntary labour would occur during times of war, with the conscription of large armies. As a consequence, armies became steadily larger, and warfare became increasingly difficult, demoralising, dangerous, and destructive. This long and continuing trend culminated in the horrors of World War II. It is to be hoped that the world has learnt its lesson, and that war is now so dangerous, and so destructive, that it will finally be abandoned.

Hydraulic Cultures

Karl Wittfogel suggested that civilisation originated mainly from the irrigation of the alluvial plains of great rivers. These rivers included the Tigris and Euphrates in Mesopotamia, the Nile in Egypt, the Indus Valley in modern Pakistan, and the Yellow and Yangtze Rivers in China. He called these civilisations *hydraulic cultures*, because of the influence of the irrigation, which led to high crop yields and very high population densities. These high population densities led to the first large-scale urbanisation. They also led to societies that were extremely authoritarian. Wittfogel argued that a single authority was essential if the irrigation was to be properly managed as a single system. Equally important, *corvée* labour was essential to build the entire system of irrigation canals and dikes in the first place. He emphasised that, in each hydraulic culture, the system of government was one of oriental despotism.

However, a similar authoritarianism, and despotism, occurred in other early civilisations, such as the Central American, which were not “hydraulic” in this sense. It seems that this despotism was a result of the high population densities, rather than the irrigated system of agriculture. The despot, after all, was only the top man in a dominance hierarchy. And both the high population density, and the dominance

hierarchy, had much earlier roots in the domestication of plants and the beginnings of agriculture. The fact that authoritarianism developed in every agricultural society is a further indication of the close similarity among human ecotypes (Chapter 3).

All the original irrigation in the hydraulic cultures was totally dependent on the natural flow of water. Canals would take the water to the fields, and furrow irrigation would take the water to the individual plants growing on ridges between the furrows. It was always a major problem, and often impossible, to get water to fields that were significantly higher than the water in the river or lake. Farmers often had to rely on annual flooding to lift water to higher levels. For example, the great lake of Tonle Sap, at Angkor, in Cambodia, drained into the Mekong River during the dry season, leaving large mud flats that were used for cultivating rice. During the rains, the reverse process occurred and the Mekong flooded into the lake, irrigating the flats once again. Similarly, farmers in ancient Egypt relied on the Nile flood to irrigate their fields which were all above the river level, except during the annual flood. An ancient system of lifting water with a *shaduf*, dates from the fourteenth century BC. This involved a bucket counterpoised by a weight at the opposite end of a long pole. But it was still very hard work, and it took a full day for one man to irrigate a single acre that was only two or three feet above the river level.

It was only much later that windmills were used to pump water to fields that were higher than the water source. The best known windmill pumps are in Holland, but these are used to drain the land, rather than irrigate it. Modern dams and pumps, of course, can handle huge quantities of irrigation water.

Rainfed Cultures

All of agriculture can be divided into the two classes of irrigated and non-irrigated agriculture. The latter is usually known as rainfed agriculture. The

irrigated river valleys of Wittfogel's hydraulic cultures occupied a very small total area. They developed great cities and civilisations because of the very high productivity of irrigated agriculture. But, in comparison, the total area available for rainfed agriculture was immense, and societies based on rainfed agriculture eventually became far more numerous and important than the hydraulic cultures.

The Poverty Cycle

However much the carrying capacity of the environment might have been increased by advances in agricultural techniques, the population always grew until it exceeded that carrying capacity. The social hierarchy involved wealth, as well as control, and the people at the top of the hierarchy always grabbed as much of the total wealth as they could. Consequently, the people at the bottom of the hierarchy always suffered poverty, including poverty of possessions, poverty of food, poverty of land, and poverty of happiness. The human population has nearly always exceeded the carrying capacity of its environment. And a stagnant and poverty-stricken peasantry has been the general rule throughout recorded history.

With each new agricultural advance, there would be a surplus of food, and the poverty would tend to decline. But, the surplus of food led to another population increase, with a further straining of the carrying capacity of the environment, and new poverty. This is the poverty cycle. Even today, there is hideous poverty, involving billions of people, in many parts of the world. Occasionally, the poverty can be disastrous, as with a major famine, or a major epidemic. There is only one solution to the poverty cycle, and that is to control the size of our total population. This means that we must finally conquer that third brutal law of nature which says that every species always reproduces in excess of the carrying capacity of its environment.

Civilisation Collapse

With every food production innovation, whether it was a new crop, or a new agricultural technique, there would be a population increase. Not infrequently, this increase would be accompanied by a surge of cultural development. Eventually, the enlarging population would grow beyond the new carrying capacity of the improved environment. If there was no further increase in food production, there could then be a population collapse and, probably, a cultural collapse as well. The whole of history is dotted with these “rise and fall” situations. The fundamental factor governing the “rise” was an increase in the carrying capacity of the environment. And the fundamental factor governing the “fall” was a new excess of people that the environment could no longer carry. Most history books will point to good and bad rulers, war and peace, as well as invasions and pestilences, as the ostensible reasons for the rise and fall of states and nations. But, very often, the rock bottom reason was whether or not the population exceeded the carrying capacity of its environment, and by how much.

Thomas Malthus

At the end of the eighteenth century, an obnoxious Englishman, Thomas Malthus, wrote an unusually influential pamphlet called *An Essay on the Principle of Population*. In it, he claimed that the human population would always grow more quickly than the food supply. As a direct consequence, he concluded that the majority of people would always have to live at the bare subsistence level.

Malthus was wrong, of course, because he did not recognise the possibility of birth control, and a stabilisation of population growth. Nevertheless, his false arguments have been used for a couple of centuries to justify poverty, and to excuse wealth. Malthus knew nothing of ecology, or even that humans, as well as wild

animals, are governed by its basic laws. Consequently, he could make no allowances for the fact that *intelligent* beings can (i) increase the carrying capacity of their environment, (ii) expand into previously uninhabitable environments, and (iii) limit the growth of their population.

His arguments would not even apply to a wild population of animals. If Malthus was right, all the individuals in that wild population would all exist at the bare subsistence level. But this is not so. The weakest go to the wall, and are lost totally. The survivors may have a struggle to survive but, nevertheless, they are vigourous, well fed, and healthy. There is no poverty among survivors in the wild.

The main reason that Malthus continues to appear valid is that we have so far failed to control our population growth. However, this does not mean that we shall continue to fail. Indeed, our rate of population growth has slowed considerably in the last two or three decades. And we can be confident that it will stabilise completely in the near future. With careful adjustment, our population will eventually be the optimum size for universal peace and prosperity throughout our total environment. And the Malthusian arguments will then be glaringly ridiculous.

Social Darwinism

Charles Darwin was greatly influenced by Malthus when he was formulating his theory of evolution. In his turn, he greatly influenced many other people who mistakenly applied his theory of evolution to the growth of human culture, and the living conditions within human society. They called this concept *social Darwinism* and they argued that, within a human society, there is a struggle for existence, and that only the fittest survive. Obviously, they said, the weak must go to the wall.

This pernicious idea was promoted by pseudo-philosophers such as Herbert Spencer in England, and William Sumner in the United States. The possession of

wealth was believed to be the result of a superior “fitness”, and differences in wealth or social class were believed to result from natural differences in ability or vigour. The concept was used to justify the class structure, and to praise the accumulation of wealth, regardless of how that wealth was acquired. It was an argument commonly used by extreme right-wing capitalists who wanted to justify the manner in which they had ruined their competitors. It was also an argument used against attempts to improve the lot of the poor.

It is now appreciated, of course, that differences in ability depend mostly on differences in education and, above all, in differences in the *opportunity* for education. A major part of education is the intellectual and emotional climate of a child’s home, quite apart from the quality of that child’s school and teachers. In a word, human ability depends on environment at least as much as it depends on genes. Social Darwinism postulates that ability, or the lack of it, depends on genes alone.

Social Darwinism is also fallacious in postulating that the laws of the jungle apply within human society. The health of any human society depends on cooperation and altruism. It does not require a struggle for existence, or the survival of the fittest. In a prosperous and peaceful society, existence should not be a struggle, and reproductive ability is no longer a measure of fitness. And we must recognise also that competition can be either destructive or constructive. While constructive competition is healthy in a human society, in everything from sports to commerce, destructive competition is debilitating, and it can destroy a society completely, if it is not curbed. The laws of the jungle, of course, involve mainly destructive competition.

Eventually, the concept of social Darwinism was taken up by racists, particularly in Germany, and it culminated in Adolf Hitler, his concept of the “master race”, his need for “living space” in the East, and his holocaust. After World War II, this vicious concept was finally discredited. It survived briefly in such ideas and

practices as *apartheid* in South Africa, but it is now dead at long last except, perhaps, in the minds of a few fanatics.

Chapter Five

Human Health

Second only to the availability of plants suitable for domestication, there is a crucially important environmental factor governing the development of civilisation, and this is human health. It must be emphasised that, prior to the development of modern medicine, human health was totally dependent on environment. Quite apart from the fact that some environments are more benign than others, both the distribution of human pathogens, and the development of epidemics, are powerfully influenced by environment.

Our Tropical Centre of Origin

Africa is the centre of origin of humankind, and our genesis is tropical. Our numerous parasites, which evolved with us, also have a tropical origin. When people migrated out of tropical Africa into the temperate regions, many of those parasites died out in the new environment, because they could not survive under the cool temperate conditions. The people who remained in Africa were at a relative disadvantage, because they had to endure some very debilitating diseases such as chronic malaria, schistosomes, trypanosomes, and other maladies. People who are chronically diseased, and who have a low life expectancy, are unlikely to develop a major civilisation, quite apart from any considerations of food supply.

Loss of Parasites

The people who migrated out of Africa into Europe and Asia lost many of their parasites. As a general rule, the further they migrated, the more parasites they lost.

The people who lived in Beringia, the dried out Bering Straight, at the time of the last Ice Age, and who later populated the whole of the New World, shed the most parasites of all. No one who was sick could have survived for long in that appalling habitat. As a result, the natives of the New World were entirely free of many diseases. These included the tropical diseases of Africa, such as malaria and yellow fever, the crowd diseases of Europe and Asia, such as smallpox and measles, the so-called children's' diseases, and the diseases associated with cattle, such as tuberculosis. And once the Bering Straight was inundated again, with the melting of the Ice Age glaciers and polar ice caps, these New World people became totally isolated from all other human populations. They consequently remained free of most of the worst of the human diseases. And they had an environment that was sensationally more healthy than the world had ever seen, prior to the development of modern antibiotics and immunisation.

Re-Encounter Diseases

All the parasites of people, plants, and animals can be divided into three categories. These categories are described as old encounter, new encounter, and re-encounter parasites.

Old encounter parasites are those which have remained in contact with their host species ever since their first evolution. An example of an old-encounter disease of people would be malaria in Africa. Similarly, in plants, a disease of wheat called rust evolved with its wild host prior to domestication, and it has been a nuisance to farmers ever since. And, with animals, foot and mouth disease evolved with wild bovines in Africa.

New encounter parasites are those that evolved separately from their new host, in another part of the world. Chagas disease is caused by a trypanosome that is

indigenous to the tropical New World. It is transmitted to people by blood-sucking bugs, and it is clearly a new-encounter disease. The AIDS virus is another obvious example of a new-encounter disease in humans. The Colorado potato beetle is a new-encounter pest that did not come into contact with cultivated potatoes until pioneer farmers moved west to the hills of Colorado.

A re-encounter parasite is one that is left behind when its host is moved to another part of the world, and then it subsequently re-encounters that host, at a later date, in its new location. The classic examples of re-encounter human diseases are all those diseases which the New World people shed in the course of their long migration from tropical Africa to the Americas.

These diseases re-encountered their human hosts when Europeans and their African slaves carried them to the New World after 1492. Another example of re-encounter diseases involves the purely tropical human parasites of Africa, which are old encounter diseases for the local people. When Europeans first went to tropical Africa, these diseases became re-encounter diseases for them. An example of a re-encounter disease in plants is the tropical rust of maize in Africa (Chapter 8). Re-encounter pests and disease are usually very damaging because the resistance of the host is lost during the absence of the parasite. This is true of people, animals, and plants, as this account will make abundantly clear.

These differences of human disease distribution led to some remarkable contrasts when Europeans began to explore the world.

Europeans and Africans in the New World

When Europeans discovered the New World, they inadvertently introduced human diseases which devastated the native peoples. The diseases included all the childhood diseases, from which young children either die, or recover, possessing

new, immunising antibodies. The childhood diseases are smallpox, measles, rubella, chicken pox, mumps, and whooping cough. Other re-encounter diseases from Europe included typhoid, typhus, bubonic plague, diphtheria, tuberculosis, and scarlet fever. People from Africa brought malaria, cholera, amoebic dysentery, leprosy, and yellow fever.

These were old-encounter diseases for the immigrant Europeans and Africans, who had antibodies to most of them. But they were re-encounter diseases for the Amerindians, who had no antibodies, and no resistance at all. When a re-encounter disease hits a totally susceptible population, it is devastating. The minority Europeans had little need to conquer these people by military means. The diseases did the work of conquest for them. The indigenous population was devastated, while the immigrant population thrived.

The areas of the New World that had the lowest indigenous population densities obviously suffered the most. These were the temperate areas of North and South America which were populated mainly by hunter-gatherers. Many tribes of these people are now extinct, and their languages and cultures have died with them. The surviving tribes of Amerindians in these areas are sadly eclipsed by the superior wealth and technology of the immigrant peoples. In spite of modern sympathy and protection, their native genes, and their native languages, will probably be swamped in a few generations by the greatly superior numbers of the immigrants.

In the agricultural areas of the New World, however, the population densities of the Amerindians were much higher, and the survival rates were also higher. In Mexico, for example, there are six million people who still speak the language of the Aztecs, and about one million who still speak the languages of the Mayas. Nevertheless, in the New World as a whole, European languages now predominate,

even if many of the people who speak these languages are of Amerindian, and mainly agricultural, descent.

Europeans in Tropical Africa

When Europeans first travelled to tropical Africa, an exactly opposite situation prevailed. This time, the re-encounter disease were indigenous, not exotic. It was the foreign invaders who were devastated by these indigenous, re-encounter diseases. These were mostly diseases which the Europeans had shed when their ancestors migrated out of Africa. It was not for nothing that West Africa became known as White Man's Grave.

The Europeans in Africa introduced no diseases that could do their work of conquest for them. It was the resistant indigenous people who carried the re-encounter diseases, which killed off the susceptible invaders. To this day, Africa is populated by Africans, not Europeans. Even in temperate South Africa, Europeans are out-numbered ten to one by Africans, in spite of their superior technology, and their brutal use of *apartheid*.

Disease vulnerability

The tragic history of human population decimation, and extinction, in the New World emphasises an important aspect of epidemiology called disease vulnerability. This term means that a population of people, plants, or animals, is susceptible to a foreign parasite which is *absent* from the area in question. The vulnerability is thus invisible and, quite possibly, unsuspected. But it is very real because, when that foreign parasite is inadvertently introduced, the vulnerability is manifested. Potential disease then becomes actual disease.

The New World Amerindians were obviously highly vulnerable to all those European and African diseases. Equally, there are many crops and domestic animals that are vulnerable to foreign parasites which are absent from their localities. One of the more important tasks of agriculturists is to identify these vulnerabilities, and to develop resistant crop varieties, and veterinary vaccines, in advance of the foreign parasites arriving.

An interesting aspect of disease vulnerability concerns smallpox. As a result of remarkable work by the United Nations World Health Organisation, this disease has now been eradicated, worldwide. The disease no longer exists. This means that it is no longer necessary for children to be vaccinated against it. But there is an ugly aspect of this story. Within one complete human generation, the entire human population of the world will become susceptible to smallpox. This constitutes a remarkable, man-made, disease vulnerability.

However, cultures of the smallpox pathogen have been maintained in several special laboratories for the purposes of manufacturing vaccines, should the need arise. This means that the *pathogen* still exists, even though the disease is no longer manifested. The disease may be extinct, but the pathogen is not. The potential damage from an accidental escape, or even from deliberate biological warfare, is fantastic. It is a more remote, but far more frightening, scenario than the thought of terrorists getting their hands on an atomic bomb. Perhaps we should reconsider the need of vaccinating our children, and ourselves, against smallpox.

People-Importing and People-Exporting Countries

It was mainly this world distribution, and redistribution, of human diseases that turned the New World and Australasia into people-importing countries. This happened simply because the local populations had had these incredible disease

vulnerabilities, and had been devastated by re-encounter diseases. No one can be blamed for this ghastly mortality, because no one knew anything of epidemiology in those days, and this was long before the days of Pasteur. Equally, no one can be criticised for moving into the vacant lands of these extinct, or near-extinct peoples. The vacant land was there, in really huge amounts, and it would belong to the first people who claimed it.

Europe, Asia, and Africa contained mainly people-exporting countries. Populations with both agriculture and resistance to diseases expanded, while populations with agriculture, but little resistance to disease, contracted. And those populations which had neither agriculture, nor resistance to disease, usually became extinct. Obviously, the expanding, crowded populations tended to move into the territory of the diminishing, uncrowded populations. Many other factors, such as commerce, warfare, and slavery, were also involved, but none of these could have influenced events as they did, without the underlying factors of population growth and decline, controlled by those two factors of agriculture and disease.

Part Two

The Major Staples

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Chapter Six

WHEAT

Domestication

The earliest wheat to be cultivated was probably a primitive form called *einkorn*, which still grows wild in the Middle East. This is a difficult wheat to grow because it has the so-called ‘shattering’ character, which means that it sheds its seed when they are ripe. To harvest this kind of wheat, each ear must be carefully picked by hand before the shattering occurs.

Later, the *emmer* wheats appeared. These were natural hybrids between einkorn, and another wild wheat, and they had the ‘non-shattering’ character. This meant that they retained their seeds in the ear, like modern wheats. Harvesting was then much easier, and more complete, because the wheat stems could be cut and carried to a threshing floor without loss.

It is, of course, perfectly normal for wild plants to shed their seeds, because this is a natural method of seed dispersal. But this characteristic is obviously a grave
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disadvantage in agriculture, and one of the more reliable indications of an ancient domestication in plants is the loss of a seed dispersal mechanism. Modern wheats do not shed their seeds and, indeed, it would be intolerable if they did. This is true of all crops that are cultivated for their seeds, such as the cereals, grain legumes, and cotton. It is also true of most other crops that are propagated by seed, such as tobacco, because the seed must be collected if the crop is to be sown.

Primitive wheats had a further disadvantage, however. They were all ‘hulled’ wheats. That is, the protective seed coat was firmly attached to the seed, and this made threshing extremely difficult. The hulls, or husks, had first to be loosened by roasting the grain. It was only with further domestication that free-threshing forms were found and preserved. These could be easily threshed by flailing, and then winnowed by tossing the grain into the wind, which would carry away the light husks, leaving the naked grain to fall to the ground.

To this day, other cereals, such as oats and barley, have this hulled character, and their husks require modern machinery for easy removal. In terms of the requirements of a major staple, they lack the criterion of ‘easy cultivation’ (Chapter 3). Throughout history, they have remained much less important than wheat for this simple reason. They have a further disadvantage in that they cannot be made into bread.

As we have seen, the domestication of plants occurred because cultivators knew that they could choose *which* seeds to sow. If a rare and valuable ‘sport’, or mutant, was discovered, such as the non-shattering, or the free-threshing characters in wheat, it would be most carefully nurtured and propagated, at the expense of the older, inferior types. These non-shattering and free-threshing characters have been preserved by farmers, from one wheat crop to the next, for about nine thousand years.

The development of non-shattering and free-threshing wheats is a classic example of how domestication produces genetic changes of great advantage to humankind, but of grave disadvantage to the plant that is being domesticated. Plants which cannot shed their seeds, and which do not protect their seeds with husks, cannot compete successfully in a wild ecosystem. It is for reasons such as these that few domesticated plants stand any chance of surviving in the wild, once they are deprived of human support and protection.

Wheat was first cultivated in the Middle East, during a period dating from nine to ten thousand years ago, in the area known as the Fertile Crescent. This is a range of hills that curves in a great arc northwards from modern Israel, then eastwards, skirting the Syrian desert, then southwards, following the valley of the Tigris and Euphrates rivers.

The earliest archaeological record of wheat dates from the seventh millennium BC, and is at a site called Mureybet, in northern Syria. The wheat is primitive, and it is the einkorn type which, as we have seen, sheds its seeds, and has hulled seeds. A later sample of both einkorn and emmer comes from Jarmo, in northern Iraq. These early sites were small villages of 100-200 people living in houses built mainly of mud-bricks. At a later stage, farmers discovered how to exploit the flood plains of Mesopotamia. This name means "between the rivers" and it refers to the Tigris and Euphrates rivers. These flood plains were so productive that there were massive population increases and some of the earliest of the large civilisations developed in this area. Eventually, huge irrigation systems were developed, and some of the greatest empires of all time developed around this centre.

At approximately the same time, two additional civilisations, also based on wheat, developed in the Nile Valley in Egypt, and in the Indus Valley in modern Pakistan. These three civilisations, along with the Yellow and Yangtze River

civilisation in China, were something completely new. The carrying capacity of the environment, and the human population density, had increased so much that major changes in the social structure became essential. Each society became extremely authoritarian, with a rigid social hierarchy ranging from a king at the top, to the lowest of slaves at the bottom.

It was with these irrigated agricultures that sedentism probably reached its limit. Every farmer was confined to a small area of land, and was normally unable to move out of it, either by force of circumstances, or because he was forbidden to do so. If they did travel, these farmers were usually moved against their will, either as conscripts for the army, or as involuntary, *corvée* labour. Even the movements of the king were constrained by the omens and rituals of priests, who represented them as the favour or displeasure of the gods. This was a far cry from the uncrowded, non-authoritarian freedom of movement of nomadic hunter-gatherers.

These were the societies, based on an irrigated agriculture, that Karl Wittfogel called "hydraulic cultures" (Chapter 4). They were characterised, first, by the irrigation and, second, by an oriental court with a hereditary god-king whose power was absolute. And they were in sharp contrast to the civilisations based on rain-fed wheat, such as the Minoan, Phoenician, Greek, and Roman. The hydraulic cultures were the first to appear, because irrigated agriculture is so productive. But, as social organisation and agricultural techniques improved, the civilisations based on rain-fed agriculture eventually grew far larger, and more important, than the hydraulic cultures. This was because they were not confined to relatively small river valleys.

Some of the hydraulic cultures suffered severely from problems of salt accumulation in the soil, when too little water was being used to irrigate too much land. This did not happen in Egypt, or in China, where water is plentiful. But it was a major problem in Mesopotamia, and it may have been responsible for the collapse of

the Indus Valley civilisation. Barley is more tolerant to salt than wheat and, for this reason, it became the main staple in much of Mesopotamia. But, as we have seen, barley has hulled seeds, and it is considerably less productive, and more labour-intensive, than wheat. Nor can it be used to make bread.

The Diversification of Languages and Cultures

When the first, migrating, hominid hunter-gatherers left Africa, with their primitive knowledge, the rate of cultural development was slow. Indeed, the rate of cultural development was much slower than the rate of migration. This meant that ancient peoples, throughout the world, had a common culture of stone tools, fire, baskets, animal skin clothing, and artificial shelters. But the rate of cultural development gradually increased, and *local* cultures began to develop. Because long distance communication was negligible, each local culture tended to be different from all the rest. This showed particularly with the growth of language, but it was also crucially important with the development of local skills. Of these skills, perhaps the most important were the domestication and cultivation of whatever suitable wild plants happened to occur in the local environment. As the growth of culture steadily increased, the differences between the various peoples in different parts of the world increased until they reach a maximum. This maximum probably occurred just when the European explorations began in the late fifteenth century. After that, the differences began to decline.

To-day, the reverse situation pertains. Large scale migration has largely ceased because every habitable spot is already occupied. The rate of communication, on the other hand, has become almost instantaneous. If a word is invented, such as an important new computer term, it can become known all over the world almost immediately. And, if a new fad appears, such as the hoola hoop, or Rubic’s cube, it

becomes known, and available, all over the world, in no time at all. As important new inventions are made, and new words to describe them are coined, they tend to become universal throughout all human cultures. The worldwide spread of television, radio, and cinema films will soon be complete. The cultural differences between the various peoples of the world are now disappearing fairly rapidly. Eventually, we shall have one universal human culture and, possibly, one universal language. Any local differences that may occur will be described as quaint and may be preserved for that reason only.

The Indo-European Family of Languages

It was Sir William Jones, a judge in Calcutta, who discovered the affinity between the dead languages of Sanskrit, Latin, and ancient Greek, in 1786. He proposed a single *family* of these languages, to which ancient Persian, and the Celtic and Gothic languages of Europe could also be added. In 1813, Thomas Young proposed the name "Indo-European" for this family of languages. Soon after this, scholars such as Freidrich von Schlegel and Franz Bopp developed the new science of linguistics.

With the publication of Darwin's *Origin of Species*, in 1856, linguists quickly realised that languages evolve in much the same way that species evolve. Intense interest then focused on the original parent of the Indo-European family of languages. This parent is generally called proto-Indo-European. What language was it? Where did it originate? How did it spread over such a huge area? And why was it so influential?

The Renfrew Hypothesis

Colin Renfrew has proposed that the spread of the Indo-European languages resulted from the spread of wheat farming. He adopted the *wave of advance model* that was developed jointly by the Italian geneticist Luigi Cavalli-Sforza, and the American archaeologist Albert Ammerman. This model proposes a slow spread of a human population, resulting from increases in the size of that population.

The wave of advance involved farmers. They were primitive farmers by today's standards, but they did cultivate wheat, and they did build permanent houses and villages. As a result of their increased food supply, and their improved shelters, they lived longer, they reproduced more, and they had a lower infant mortality, than their hunter-gathering neighbours. Their population densities were perhaps fifty times greater than those of hunter-gatherers. This was probably the biggest increase in the carrying capacity of the environment that pre-historic people ever achieved.

However, these farmers continued to reproduce beyond the carrying capacity of their environment. The younger sons and daughters of farmers would thus move into the territory of the hunter-gatherers, in order to start farms of their own. This movement was probably quite peaceful. It would involve a small spread with each human generation. From one generation to the next, the hunter-gatherers would scarcely notice this slow encroachment on to their land. But this rate of advance would take people right across Europe in one or two millennia.

This wave of advance is thought to have started in Anatolia, in southern Turkey. The recently excavated town of Çatal Hüyük (pronounced Shatal Hoo-Yook), on the Çarsamba River, in southern Anatolia, was probably built by these wheat farmers. The site was founded in about 7000BC and it covers thirteen hectares, although only a small amount of it has been excavated so far. The whole town predates the cities of Mesopotamia by some 3000 years. It contains an estimated 1000

houses, and it probably had a population of 5000-6000 people. These houses are remarkably uniform in their size and layout. They are built of mud-brick, and they touch each other, without streets between them. The entrances are through the roof, and some of the houses have open courtyards. A fascinating feature is the frequency of shrines with obvious fertility cults, and bull's horns, that suggest a cultural link with the much later, but very similar Minoan cult objects in Crete and, possibly, Roman Mithraism.

Even though it was built and occupied by farmers, Çatal Hüyük was also an important centre for trade, and it developed skilled craftsmen of various kinds. A nearby site called Çayönü has some of the earliest metal working in the Near East. Vegetable remains show that these people cultivated wheat, barley, peas, lentils, and vetches. They also collected wild apples, pistachios, almonds, and acorns. The importance of their cattle was indicated by their art, and their religious representations of bulls. Sheep and goats had also been domesticated, and pigs were being utilised, if not actually domesticated. But the hunting of wild animals was still important. Compared with the hunter-gatherer way of this life, Çatal Hüyük provides a dramatic picture of the almost instant effects that agriculture and sedentism can have on the beginnings of civilisation.

It seems that the language of these southern Anatolians was the original parent of the entire family of Indo-European languages. It was proto-Indo-European. From towns such as Çatal Hüyük these farmers spread their language and their genes into most of Europe, into the Caucasus, the Middle East, and through Persia into northern India. Some three thousand years later, the spread was complete. It could go no further because it had reached natural barriers in every direction. These barriers, obviously, were mainly the geographic limits of wheat growing in the hunter-gatherer areas of Eurasia. A few places, such as northern China, already had a primitive

agriculture based on millets, and the Indo-European wave of advance could not penetrate into these areas of high population density.

As their initial numbers increased, these southern Anatolians slowly spread into the land of the hunter-gatherers, taking their language and their genes with them. And the hunter-gatherers slowly declined in numbers, as their territory diminished. They could not fight back because they were numerically so inferior. It seems that they had only two options. They could retreat and decrease in numbers as their land decreased in area. Or they could integrate with the agriculturists, probably by inter-marriage, adopting both their agriculture and their language. In either event, their languages and genes would be swamped by superior numbers, and would all but disappear. However, they did not disappear entirely. It is possible that their languages, and their genes, still survive in a few small pockets of Europe, such as the Basque country, that are unsuitable for wheat farming, and which still have a language that is not Indo-European. Hungary and Finland also have languages that are not Indo-European languages but these came from more recent invasions.

Two apparent anomalies merit explanation. The North African languages are not Indo-European. Wheat culture apparently spread by cultural diffusion, rather than by the spread of people in a wave of advance, into North Africa, and up the Nile Valley as far as the Ethiopian highlands.

Second, the other major wheat civilisations were in Mesopotamia, in the Tigris-Euphrates valley. In theory, it is these civilisations that should have become the founders of a major family of languages. But they did not for a very simple reason. The people of southern Turkey, and of towns such as Çatal Hüyük, cultivated rain-fed crops, not irrigated crops. The distinction is crucial in relation to the spread of language.

The agriculture of Mesopotamia was based on irrigation with river water. Initially, the farmers occupied the flood plain, and they relied on natural flooding. Later, they developed dams, irrigation channels, and similar forms of water control. This irrigated agriculture can be highly productive but, obviously, it is confined to river valleys and flood plains. These people may have conquered large empires but, it seems, conquest does not spread languages nearly as effectively as agriculture.

Rain-fed agriculture is less productive than irrigated agriculture, but it does have the advantage that it can spread into any temperate area that has an adequate rainfall. The limits of rain-fed wheat cultivation were remote, far beyond the confines of the known world at that time. This explains why it was the wheat farmers of Anatolia, rather than the wheat farmers of Mesopotamia, who spread a new family of languages across an area extending from the western shores of Europe to India. The geographic limits of rain-fed wheat were defined by climate, and not by a mere river valley, however large, and however important it may have been, in the history of civilisation.

Much more recently, there was a further spread of the Indo-European languages that also followed the spread of an agriculture based on wheat. This occurred in the New World, in Australia and New Zealand and, to a limited extent, in Africa.

The indigenous peoples of the temperate North and South Americas had the low population densities of hunter-gatherers, further reduced by re-encounter diseases such as measles and smallpox. In these areas, it was the indigenous peoples who often became extinct, or who remained a minority, and it was the incoming agriculturists, who quickly overwhelmed them by sheer numbers.

It was the agricultural peoples of the tropical Americas who survived the trauma of European discovery, because of their high population densities, and it was

the hunter-gatherers of the temperate regions of the Americas who all but disappeared, because of their low population densities. The same is true of the languages of these peoples. It is the European languages which now dominate the Americas, and the indigenous languages which have become extinct, or very nearly so. Those indigenous languages which survive are mainly the languages of agriculturists, and not those of hunter-gatherers. A similar story can be told of Australasia.

It is interesting to note also that the mingling of peoples was ruinous to the indigenous people of the New World, mainly because of re-encounter diseases. However this did not apply to the mingling of crops. And the Old World people benefited greatly from their adoption of New World crops, particularly potatoes, maize and beans. It was only several centuries later that these crops began to be ravaged by re-encounter diseases, as the Chapters on maize and potatoes will explain.

Evidence of a wave of advance by agriculturists can be seen in other parts of the world. In eastern Africa, for example, it is likely that the southward spread of the Bantu people, and their languages, resulted from the gradual replacement of Khoisan hunter-gatherers by Bantu farmers. And, as we shall see (Chapter 9), the coconut was responsible for a rather different kind of dispersal of language.

Storage

Closely associated with the earliest wheat cultivation was wheat storage. As already mentioned, storage is a basic requirement of any staple food. Effective storage is essential if there is to be a steady supply of food from one harvest to the next. It is also essential if a civilisation is to survive the occasional, but inevitable, bad harvest. Cereal storage bins, or granaries, were a feature of all the early farms,

villages and cities. Indeed, without a reserve of storable food, these permanent settlements could never have developed in the first place.

The granaries were built at least as strongly, and as securely, as the houses themselves. If the store of food was lost to flood, fire, theft, or conquest, then all else was lost too. People who guarded and defended their homes, villages, and cities were defending their supply of food at least as much as they were defending their homes and themselves.

Stored grain had a second function also. It represented wealth, and it could be used as money before the days of currency. Grain was thus a medium of exchange in all forms of ancient trade. It could also be used to pay taxes.

Storage Pests

A major problem was to protect the granaries from non-human thieves. The most visible of these pests were rats and mice. These animals alone justified the building of granaries with well-fitting stone. Cats were apparently domesticated at the time of the first cities for the sole purpose of controlling rats and mice.

Much more insidious are the insect pests of stored grain, which are mainly weevils. These tiny pests have a very high multiplication rate and they can quickly reproduce to an enormous population. They can easily destroy the contents of a granary before the next harvest is ready. The easiest method of controlling them is to deprive them of oxygen. Early storers of grain discovered, quite empirically, that granaries should be airtight, and that the entrance should be at the top. They could not explain why this was effective, but we now know that the first insects to infest the grain consume all the oxygen, replacing it with carbon dioxide. Once the oxygen falls below a critical concentration, all the insects die. The carbon dioxide is heavier than

air and, if the granary entrance is at the top, this gas does not easily escape when the entrance is opened for the removal of grain.

Even smaller than the insect pests are the various moulds that can also destroy stored grain. Mouldy grain is unfit for consumption, particularly as some of the moulds are poisonous. However, these fungi can only grow if there is an adequate moisture level in the granary. Provided the grain is well dried before storage, moulds are not usually a problem.

Milling

The earliest milling of wheat was probably done by crushing the grain between two stones, called querns. Alternatively, the grain would be pounded in a wooden mortar, using a long and heavy pestle that is lifted high over the head. This kind of milling can be seen to this day, on subsistence farms in many non-industrial countries, and it is used for pounding root crops as well as for milling cereals. Much later, millstones were developed. One millstone, like a hollow cone, or hat, would be rotated on top of another, which was a solid cone, or head. There was a hole in the centre of the top millstone, and the wheat would be poured into the hole, and ground into flour between the two stones. The flour would fall off the edge of the bottom stone. Ancient Roman millstones of this design were found in Pompeii, with an arrangement for the use of animal power. The top stone would be rotated by a donkey, or an ox, walking in circles round the mill. The Romans also developed water mills.

Later, there was a new design of horizontal millstone that was flat. The bottom stone was stationary, and had grooves radiating from its centre. The wheat was poured through a hole in the centre of the rotating top millstone, and the flour fell off

the edge of the bottom stone. The best millstones were made from French buhrstone, quarried near Paris, or from an English rock called millstone grit.

An old mill is a characteristic of many streams and rivers in Europe, situated where there was a good fall of water. In very flat countries, such as Holland and the English Fens, wind power was utilized. Hence the term windmill. Many towns in the United States and Canada are situated on a river, often near a waterfall. The oldest buildings in the town, if they still exist, are the grist mills, where farmers would bring their grain to be ground into flour. They were called grist mills to distinguish them from other kinds of mill, such as sawmills, cotton mills, paper mills, and steel mills.

Equally important, before the days of steam railways, river barges were the only means of transporting heavy goods in bulk. A waterfall thus represented both a source of water power, and a barrier, possibly an upstream limit, to river transport. It was always the most logical place to build a new town.

Cooking

The earliest method of cooking wheat was probably to roast the entire grain on hot fire stones. With the first milling of the wheat, it was discovered that the crushed grains, mixed with water, would produce a gruel. It was discovered that this gruel could be cooked by pouring it onto a hot, flat stone. This would produce a sort of pancake, the “unleavened bread” of the Bible, very similar in taste and texture to the modern Indian *chapatti* and, except for its being made with maize flour, the Mexican *tortilla*.

This method of cooking both wheat and maize is an excellent example of parallel cultural evolution, in which the same development occurs more than once in different parts of the world that have no cultural links with each other. The pyramids of both ancient Egypt and ancient Meso-America are another example. Some

historians try to argue that these parallel developments indicate that these ancient peoples must have had contact with each other. But this argument is false. After all, dropping some gruel on to a hot stone must be one of the most obvious of ancient cooking methods. And either a cone or a pyramid was the only way of building a really tall structure, before the days of strong vertical walls. (There is a circular, step 'pyramid' in Mexico, but none in the Old World). Tall structures were essential if temples were to be near to the sky gods.

The ancient Egyptians were apparently the first people to make leavened bread, in which the dough is left to ferment with yeast. Yeast produces carbon dioxide gas which gives the dough the sponge-like texture of bread as we know it. Until very recently, wheat was the only cereal that could be made into a light, sponge-like bread. This is because wheat contains a mixture of proteins collectively called gluten. When wheat flour is wet, the gluten makes the flour particles adhere to each other. The dough can then be stretched like putty. And it can be filled with gas bubbles, like sponge rubber or foam plastic. However, when the dough is cooked, these properties of gluten are lost, the nature of the starch is also changed and, in this way, the dough is converted to bread.

In the early days of wheat domestication, wheat and barley were of almost equal importance. Indeed, as we have seen, in some irrigated areas, barley largely supplanted wheat because it is tolerant of salty soils. In the long run, however, wheat proved more important because it can be made into leavened bread, while barley cannot. And, as we have seen, wheat has the free-threshing character, while barley does not. These differences are seen to this day, when the total acreage of barley is very small, when compared with that of wheat, and barley is grown only for making beer, or for animal feed, and there is no such thing as barley bread.

Two Kinds of Wheat

The modern cultivated wheats are classified into two species which differ mainly in the amount of gluten they contain. The durum wheats (*Triticum durum*) have a very high gluten content. They produce flour suitable for making *pasta*. This kind of wheat needs a hot, dry, Mediterranean climate where bread wheat grows only poorly. This is why the various pastas are the staple diet of Mediterranean peoples, and they have mostly Italian names, such as macaroni, spaghetti, linguini, cannelloni, and fettucini. In France, spaghetti is called *nouilles,* from which the American term “noodles” is derived.

Pasta can be made into an endless variety of shapes and sizes, including the letters, called *alfabeti* in Italian, used in alphabet soup. In North Africa, durum wheat is the staple food but it is not made into pasta. It is crushed into a very coarse flour known as *semolina*, and it is boiled as a delicious savory called *cous-cous*, which resembles very small rice grains. In England, semolina is commonly used to make a sweet milk pudding.

Bread wheats (*Triticum aestivum*) have much less gluten, but they too are classified according to their gluten content. Those with a relatively high gluten content are called “hard” or “strong” wheats, and those with a low content are called “soft” or “weak” wheats. The hardness refers to the wheat grain itself, and the ease with which it can be crushed. The strength refers to the dough, and its ability to stretch without breaking. Bread requires a strong wheat, which produces a dough that stretches well. The weak wheats produce a non-stretching dough, and they are used mainly for making brittle cookies and biscuits. Modern flour is usually a blend of weak and strong wheats, designed to have exactly the right amount of gluten. Egg whites can be used as a substitute for gluten, and it is possible to make pasta from

bread wheat by adding eggs to the flour. Eggs can also be added to weak flour in order to make sponge cakes.

Recently, a research team from the Food and Agriculture Organisation of the United Nations discovered how to make leavened bread from starch that contains no gluten, such as the flour made from rice (Chapter 7), maize (Chapter 8), or tropical roots. This is done either by adding a gluten substitute, such as xanthan gum, or by boiling a little starch in water to produce a thick gel, which is then added to the dough. This is important because bread has become increasingly popular among urban people in non-industrial countries which usually cannot grow wheat. This is not surprising, because bread is the most popular food of all, worldwide. It is also one of the cheapest, and most useful, of the convenience foods, requiring little preparation before being eaten. But the imports of wheat have become a serious economic drain in many of these countries, and the substitution of locally produced starch for bread making will lead to considerable savings of scarce hard currency.

Bread

It was the ancient Egyptians who developed the first ovens, and they also discovered the art of leavening bread, in about 2,600 BC. This must have been an accidental discovery, made from gruel that had been inadvertently neglected. The Egyptians also discovered how to prime new dough with a little sour dough left over from the previous baking. In this way, a continuous culture of baker's yeast was maintained. The yeast leavens the bread by fermenting sugars in the dough, producing carbon dioxide gas and alcohol. This is why dough must be left for several hours to rise before it is cooked. The gas produces the sponge-like texture of the bread, and the alcohol contributes to the wonderful taste and smell of newly baked bread. However, fresh bread does not contain enough alcohol to intoxicate.

Leavening was traditionally achieved with yeast, but it is also possible with bacteria, chemicals, such as baking powder, or by the folding in, or injection, of air or gasses into the dough. Bakers' yeast is a microscopic, single-celled organism called *Saccharomyces cerevisiae*. It reproduces very rapidly by budding off new cells, and it obtains its energy by breaking down sugars into the less complex substances of carbon dioxide gas and alcohol. Carbon dioxide gas is the key factor in making leavened bread. The rate of fermentation, which is controlled mainly by temperature, determines the rate of gas production, and this governs the texture of the bread. Rapid gas production produces a very coarse bread, with large holes, while a slow fermentation results in a very fine, even textured bread. The texture also depends on how thoroughly the yeast is mixed into the dough. Kneading the unleavened dough helps to reduce its coarseness and its unevenness.

The texture of the bread can also be controlled with the rate of carbon dioxide production from baking powder. This chemical is a mixture of dry sodium bicarbonate, and a dry powder acid, such as tartaric acid. When it becomes wet, the two chemicals react with each other to produce carbon dioxide gas. Modern baking powders are often double acting, giving off some gas on wetting, but even more gas on heating, during baking.

Sponge cakes and angel food cakes are artificially leavened by trapping air in the dough with vigorous beating. An explosive production of water vapour can be used to leaven pastries which are cooked at high temperatures. Puff pastry and *vol-au-vents* obtain their special light textures in this way.

The ancient Egyptians are reputed to have had over fifty different kinds of leavened bread, with a great variety of flavours, shapes, and sizes. The ancient Greeks were apparently backward in this respect, and their bread was in the form of unleavened, flat cakes, often sweetened with honey.

Ancient Rome

In Imperial Rome, bread was the staple food, and cynical emperors used the phrase "bread and circuses" to describe the two prime requirements of government, necessary for keeping an unruly populace quiet. For this reason, there was strict government control over the manufacture and sale of bread in the ancient Roman Empire. Monopolies were frequently formed, and trade guilds were created to control both the milling of flour, and the baking of bread. Later these guilds became rigidly institutionalized, with inflexible rules, and hereditary membership.

Ancient Rome obtained much of its wheat from Egypt, which Augustus had conquered from Cleopatra, lover of Anthony, and the last of the Ptolomies. Augustus then decided that the whole of Egypt belonged to him, as his own personal estate. This was the source of most of his power because, if things went badly for him, he could always threaten to retreat to Egypt, and to cut off the supply of wheat. This wheat was also the source of much of his enormous wealth although, to do him justice, he made no distinction between his private purse and the public purse. Later emperors also regarded the wheat supply as one of the most important, non-military factors in politics.

Egypt

Unlike Italy, which has mostly a rain-fed agriculture with dry Mediterranean summers, Egypt is immensely fertile because of the irrigation with the annual floods of the Nile. There is an archaeological myth to the effect that this fertility is due to the silt which is carried by the Nile and deposited on the fields of the river valley during the annual flood. This is a classic example of an error which has been uncritically copied from textbook to textbook over many decades.

The myth is false for two reasons. Firstly, plant nutrients are mostly soluble and, regardless of how many nutrients may have been present in the silt originally, few would remain by the time it was deposited on the Egyptian fields. If the silt was to have nutritive value, there would have to be a lot of it deposited each year.

Secondly, true silt is insoluble and, once it is deposited, it is likely to stay there for ever. If an average of one centimetre of silt were deposited each year, the level of the fields would rise above the level of the river by about one meter every century. They would now be 40-50 meters higher than in the days of the First Dynasty. Even a deposit of one millimetre of silt annually, which could not have any nutritive value for plants, would have now raised the fields by 3-4 meters. There is no archaeological evidence for even this amount of sedimentation.

A final possibility is that the silt is totally organic in composition, having originated in the Nile Sudd, which consists of a huge swamp filled with floating islands of papyrus. The water would then contain organic nutrients which would decompose entirely in the farmers' fields. The chain of errors would then be only etymological, because true silt is inorganic. However, for the Nile to carry enough organic nutrients to benefit agriculture would make it little short of an open sewer. And the river itself would be choked with floating water weeds.

The true value of the Nile flood is in irrigation. Egypt, after all, is located in the Sahara desert and, without the river water, plant growth is impossible. Egypt has a further advantage because irrigated crops grown in a dry atmosphere often produce more than rain-fed crops. This is because the dry atmosphere ensures that they are relatively free from pests and diseases. But this fertility has nothing whatever to do with silt deposited by annual floods.

Nowadays, the plant nutrients in Egyptian agriculture come from artificial fertilizers. In the old days, plant nutrients were often deficient, and yields were lower

as a result. Some amelioration was obtained from the use of ashes, crop residues, animal dung, and human excrement as manure. The ancient Egyptians also grew leguminous plants, such as berseem clover (*Trifolium alexandrinum*), which fix atmospheric nitrogen and add it to the soil (Chapter 3). But this is a digression.

Mediaeval Europe

In Europe, in the Middle Ages, bread making was also controlled by guilds. However, these medieval guilds were in the nature of cartels, designed to protect the producers, rather than the consumers. The guilds would possess special skills, which were trade secrets, to be carefully guarded in order to prevent competition. The trade secrets would be taught only to privileged apprentices, who were usually the sons of guild members. A successful apprentice would first be promoted to the rank of journeyman, employed by other bakers and, later, he would become a master baker, possibly owning his own bakery.

In country districts, bread was always made at home. It is perhaps a measure of the quality of commercial baker's bread that, even in those days, home-made bread was considered the best. A farmer's wife who stooped to buying baker's bread was considered a domestic disaster. For this reason also, a good farm wife would make her own beer, butter, cheese, bacon, ham, sausages, pickles, pastries, and preserves. Perhaps, with increased leisure in the age of the information revolution, people will be able to return once more to the high quality, and the delight, of home made foods.

Pastry

Bread may be the most important food in the world, but there is a further aspect of wheat utilization which should not be overlooked. This is in the cooking of wheat flour with sugar, to produce a wide range of sweet products, such as cakes, pastries,

and cookies. One of the main features of this kind of cooking is the addition of fats, or cooking oil, to the flour and water mixture. This is known as "shortening" and it produces both a more brittle product, and a flavour of its own, particularly when butter is used. Bread usually has only 1-2% shortening, cakes have 10-20%, and pastries have up to 30%, while pie crusts and dumplings have even more.

Eventually, cake and pastry making became such an art that it was detached entirely from bread making, and pastry cooks often had their own establishments, entirely separate from bakers. The range of pastries was far greater than the variety of breads, because innumerable embellishments were possible in the way of nuts, fruits, chocolate, custard, whipped cream, marzipan, icing, and colouring. Many different spices, such as vanilla, ginger, and allspice, could also be used. The possible variety is infinite, but many of the traditional cakes and pastries remain firm favourites.

Pastry shops were often tea shops also, and many became famous as social meeting places for the rich and the elegant. More recently, in our calorie-conscious age, pastries have suffered a decline. They are, indeed, very fattening, and should be consumed with restraint, which is often difficult, because they are so tempting. Self-discipline has been described as the ability to eat only one cashew nut at a cocktail party. Alas, self-discipline is even more difficult with pastries. Perhaps, as Oscar Wilde commented, the only way to get rid of temptation is to give in to it, although the old reprobate was not referring to pastry.

The Industrial Revolution

From the early nineteenth century onwards, wheat production, and the making of bread and pastries, were transformed by a series of remarkable innovations. In wheat production, the greatest bottle-neck had always been the process of reaping. It was necessary to cut the wheat in order to harvest it and, later, to thresh it. Reaping

was traditionally done with a scythe, and the cutting down of thousands of wheat stems made such an impression on peoples' minds, that death was represented as "The Grim Reaper", a cloaked skeleton carrying a scythe on his shoulder, possibly dating from the horror of the black death in the thirteenth century.

Wheat must be both ripe and dry when it is harvested. In areas of rainfed agriculture, there are usually only a few days each Fall when reaping is possible. The demand for manpower was greater during this period than at any other time in the farming calendar. Because the labour was scarce, it was also expensive. If the labour was not available at the right time, the wheat was liable to be soaked by rain and, as bulk dryers did not exist in those days, it might well be ruined. In any bread-eating country, this labour bottle-neck determined the total size of the wheat crop and, hence, the price of bread, the supply of the staple food, and the population density of the country in question. Once again, the carrying capacity of the environment had reached a limit.

This limit was breached first by the utilisation of three crops from the New World. These crops were maize, potatoes, and beans. Maize (Chapter 8) is considerably more productive than wheat, and its harvesting can be spread over a period of time, because the grain is well protected by a sheath that covers the entire ear. Maize became a basic food for poor people in the Balkans and much of southern Europe. Potatoes (Chapter 11) became a basic food in much of northern Europe, which was too cold for maize. Beans, having a wider climatic range, became an adjunct in both southern and northern Europe.

The bottle neck of wheat harvesting was further reduced by the invention of mechanical harvesters. These developments represented a major increase in the carrying capacity of the environment and, during the nineteenth century, the population of Europe increased dramatically. As a direct consequence, the

populations of temperate North and South America, and Australasia, increased even more dramatically as surplus people from Europe poured into these under-populated areas.

The Scottish pastor, Patrick Bell, designed the first mechanical reaper in 1828. He took it to Canada in 1833. However, independently, at almost the same time, and much more successfully, Cyrus Hall McCormick built his first mechanical reaper in 1831, in his workshop at Walnut Grove, in the Shenandoah Valley, Virginia, when he was only twenty two years old. This machine had the three essentials of all subsequent models. It had a reel to bring the standing wheat to the cutters, it has an oscillating blade to cut the wheat, and it had a platform to collect the cut stems. Its main defect was a clattering noise so loud that it frightened the horses and, indeed, this was the beginning of noisy agriculture.

Anyone taking a walk in the country these days is unlikely to get away from the widespread reverberations of powerful diesel engines on farms. Before McCormick, it was the towns that were noisy, with numerous iron-tyred wheels, and iron-shod horses, all clattering over cobble stones. And it was the farms that were quiet, with the loudest noise being the clucking of chickens, or Mary calling the cattle home, across the sands of Dee.

Sixteen years later, in 1847, McCormick had improved his machine sufficiently to justify his own factory. He started up in Chicago, and he showed extraordinary commercial initiative and innovation. He was among the first to use mass production, product warranties, customer credit plans, public demonstrations, and advertising. In some of his manufacturing innovations, he was more than half a century ahead of Henry Ford.

By 1850, McCormick's reaper was known to every farmer in the United States and, the following year, he began to export it to Europe. His reaper won the Grand

Prize at the Great Exhibition, in London, in 1851. Five years later, he was selling more than 4000 machines a year, and the bottle-neck of reaping was gone for good. This was a classic example of how a single technical breakthrough can increase the carrying capacity of the human environment. The French were so impressed, they gave McCormick the Legion of Honour.

Free Trade

In Britain, in the 1840s, the corn laws were repealed and a new era of free trade began. These corn laws were protective legislation designed to assist British farmers and landowners. As a result, the price of bread was maintained close to the scarcity levels of the Napoleonic wars. But when the great potato famine (Chapter 11) gave its name to the "Hungry Forties", the necessity for cheap food became paramount. With the repeal of the corn laws, a new market for wheat had suddenly appeared, and the only countries that could supply this new demand were the United States and, later, Canada.

The American Wheatlands

At about this time also, a strange and rather horrible invention transformed the American West. Much of the Great Plains was ranching land, and cowboy country, made famous beyond its just deserts by Hollywood. It was an area of lawlessness and conflict. Shooting is not a particularly civilised way of resolving conflicts, even if it does make for good theatre. Many of the conflicts arose between rival ranchers occupying increasingly crowded ranch land. They also arose between the ranchers and a new breed of settlers who wanted to cultivate crops and, above all, to cultivate wheat. But wheat and cattle do not mix, and there could be no question of fencing in the wheat with the traditional, and expensive, wooden fences, hedges, or stone walls

of Europe. This was both because of the cost, and the inescapable fact that neither timber nor stone was readily available in the Great Plains, and hedges take time to grow.

Barbed wire was the invention that transformed the West because it provided cattle-proof fences that were cheap and easy to erect. Barbed wire meant that ranchers could confine their cattle to their own land. And it meant that wheat farmers could keep other people's cattle out of their wheat. Suddenly, wheat farming became a practical possibility, and both the new markets opening up in industrial Europe, and mechanical harvesting, made it an attractive crop to grow.

It was only later that more sinister and uncivilized uses were found for barbed wire in the control of people. To this day, barbed wire can be found in public parks, and cities, when callous bureaucrats are inadequately supervised. It first attained military significance during the American Civil War. Barbed wire reached its climax of horror in World War I when, combined with the machine gun, it resulted in a man-proof barrier that was lethal. There was then a stalemate which the conservative military commanders on both sides were too stupid, and too closed-minded, and too brutal, to comprehend. They continued to attack the enemy lines in the old-fashioned way, with walking soldiers, for four stupid, repetitive years. The barbed wire stopped the men, and the machine guns killed them. Eight *million* soldiers died, quite unnecessarily. The total bereavement caused by the deaths of all these young men is beyond human understanding.

More recently, the manufacture of barbed wire has been greatly "refined", if such a word can be applied to such an abomination. This was the invention of razor wire which is so vicious that cattle farmers would not dream of using it. Indeed, its only use is against people and, typically, it is only rather nasty authoritarians, such as

prison guards and the military, who mis-employ it in this way. But this is another digression.

In addition to barbed wire, another invention helped to transform the West. This was the wind pump. Cattle need a daily supply of water, but streams and rivers are few and far between in the great plains. However, there is plenty of ground water, quite close to the surface. The small wind pumps, driven by a wind vane, on top of a timber or steel trellis, became one of the most typical sights of the area. The pump would fill a long drinking trough for the cattle. The wheat farmers each had one also, to provide household water.

Ploughing

In order to grow wheat, the land must be tilled. The soil must be turned to improve its structure, and to control weeds. This was done by ploughing and, traditionally, the ploughshare was made of wood, in spite of the old saying about turning swords into them. This imposed severe limits on the quality and the depth of the ploughing, as well as the total amount of ploughing, because wooden ploughshares wear out quite quickly. The wooden ploughs were often reinforced with a steel cutting edge (possibly made from an old sword) but, even so, they were fragile and imperfect tools.

The first major improvement to the plough was made in England, by Robert Ransome, who produced a cast-iron ploughshare in 1785, and a self-sharpening ploughshare in 1803. In the United States, in 1830, an Illinois blacksmith, John Deere, designed an all-steel plough capable of handling the difficult black prairie soils. His plough was so efficient that it also needed fewer horses to achieve the same depth of ploughing. Iron ploughs were not always readily accepted, however. In Poland, for example, the introduction of iron ploughs happened to be followed by a

series of bad harvests. The peasants immediately blamed the new ploughs, and insisted on returning to their old wooden contraptions.

Until the industrial revolution, the main source of motive power on farms was the horse. With the invention of steam engines, much more, and much cheaper, power became available to farmers. Steam permitted far more efficient ploughing, often with ploughs pulled by cables between a pair of stationary traction engines. Improved ploughing led to improved fertility, and improved weed control. These new steam engines would also provide power for other new kinds of farm machines, particularly threshing machines. Later, of course, steam gave way to the internal combustion engine, and the farm tractor.

Harvesting

Gradually, the mechanical reaper was improved and made to undertake some of the other tasks of harvesting. The end-product of these developments was the self-propelled combine harvester that can reap, thresh, and winnow the wheat as it travels though the field. The straw is chopped and, with the chaff, returned to the soil, although many wheat farmers prefer to burn the straw and chaff as an aid to controlling pests and diseases. The wheat itself is stored in a large hopper which can be discharged into a moving truck without any interruption of the harvesting. Modern combine harvesters have two-way radio communication, air-conditioned driver's cabins, and powerful headlights which enable them to work around the clock. It is probably only a matter of time before they are fully automated.

Threshing

Traditionally, threshing was a two-step operation. First the wheat was separated from the chaff, either by beating it with flails, or by making oxen walk all

over it. Then it was winnowed by throwing it into the wind. The light chaff would be carried away by the wind, and the heavy grain would fall to a mat, where it could be collected.

With the industrial revolution, stationary threshing machines were developed and they were in use until quite recently. I can remember seeing one as a child, shortly before World War II. The machine was powered by a very long belt that linked it to a steam traction engine that was thundering away. There was a lot of smoke from the engine, and a lot of noise from both machines. The threshing machine also produced great clouds of dust. There would be lots of people around, mainly farmers bringing their horse-drawn wains laden with wheat sheaves, and waiting their turn at the thresher. But there were plenty of on-lookers also, mainly kids like myself, fascinated with the bustle, clatter, smell, and romance of it all.

Transportation

Before the invention of railways, the only feasible method of transporting heavy goods in large quantities was by water. In practice, this meant coastal shipping, which could penetrate inland only by going up the rivers. In the United States, the transport link between the wheat belt and the sea was the Mississippi, with New Orleans as its sea port. This was a long and expensive route between the prairies and the industrial East Coast, to say nothing of Europe. However, in 1825, the Erie Canal was opened. This historic waterway connected the Great Lakes with New York City, via the Hudson River.

The effect of the Erie Canal on trade and commerce was dramatic. The cost of freight dropped from $100 per ton to $10 per ton. Settlers streamed out to the West, to Michigan, Ohio, Indiana, and Illinois. Their farms suddenly became very profitable because they could now ship produce directly to the East Coast. And a constant

stream of manufactured goods went from the East, to the new farming States. As a direct result of the new transport system, New York City became the number one city in America, if not the world. And, at the other end, Chicago became the number two city, the “Second City”.

A succession of three Welland Canals were built in Canada. These linked the Great lakes to the St. Lawrence River, with a series of giant locks that lifted ocean-going ships the height of Niagara Falls. The first Welland Canal was opened in 1829, and the latest was opened in 1932. It became a key link in the St Lawrence Seaway which, however, was not opened until 1959. This seaway carries large, ocean-going ships, and it made Atlantic ports out of towns such as Thunder Bay and Duluth, which are located on the western shores of Lake Superior, and which are nearly as far from the Atlantic as from the Pacific.

The inspiration for these canals probably came originally from the Languedoc canal, in France, which was started in 1666, and completed in 1692. This incredible engineering feat links the Atlantic Ocean to the Mediterranean, via the Garonne River, which flows into the Bay of Biscay, at Bordeaux, and the Aude River, which flows into the Mediterranean, near Narbonne. The canal is 220 miles long, it has one hundred locks, with a large summit reservoir to keep them filled, three large aqueducts, and other remarkable innovations. The canal also goes through a tunnel, near Béziers, which is of historical interest because it was here that explosives were first used for blasting rock.

With the invention of railways, transport links with the American West were improved even more, and the great steel town of Pittsburgh grew rich, famous, and dirty, owing to the insatiable demand for steel railroad track.

Mary had a little lamb,

Its fleece was white as snow,
Mary took it to Pittsburgh,
And now look at the damn thing.

The prairies of the United States and Canada became the bread basket of the world. Today, some of the wheat fields stretch all the way to the horizon and, at harvest time, gangs of combine harvesters can be seen disappearing into the distance. Similar scales of production are to be found in Russia, Argentina, Mexico, and Australia. If the world were compelled to return to pre-industrial agriculture, several *billion* people would die of starvation. This is perhaps the best indication of how our cultural evolution has increased the carrying capacity of our environment.

Milling

With the industrial revolution, new kinds of flour milling machinery also became available. Millers were no longer dependent on millstones, which were replaced by steel rollers. And, with the invention of the steam engine, they were no longer dependent on water wheels, and windmills. With accurately machined steel mills, powerfully driven by steam, it became possible to mill wheat grains very precisely. This permitted the removal of the seed coat, the bran, before the grain itself was milled to flour. The resulting flour was described as white and, in 1865, for the first time, white bread became cheaper than brown bread in Britain.

Flour which is made with the whole kernel is called wholemeal, or graham flour. It is liable to become rancid with prolonged storage, because of the high oil content of the bran. One advantage of white flour is that it can be preserved for longer periods without spoilage. The bran itself used to be regarded as a largely valueless by-product, and it was usually sold to farmers for animal feed. It was realized only

much later that the bran has nutritive values of its own, in the form of vitamins, proteins, and fibres, and then wholemeal, or brown, bread once again became popular.

Modern Baking

The industrial revolution also transformed the baking industry. Mechanical mixers and kneading machines replaced muscle power, and commercial bakers no longer had to knead the dough with their bare feet. The batch oven was replaced by the continuous oven, in which a nonstop line of bread travels through a long tunnel of an oven on a moving belt. Bread making became less and less of an art, and more and more of a mass-production process.

More recently, the nutritive value of bread began to be improved with additives, such as vitamins, and mineral supplements. Preservatives are now used to increase its shelf-life. The sale of pre-sliced bread is also a relatively new development. It is, in fact, a very old idea which had to wait for the development of moisture-proof plastic film, because sliced bread is so vulnerable to desiccation. Another recent development was the discovery of a different strain of yeast that produces the so-called “sponge” bread that has the advantage of remaining fresh for much longer. It is also even further removed from the delights of home-made bread.

Perhaps the most recent development of all is the automatic bread-maker. A housewife need only add the ingredients and press a button and, a few hours later, the machine produces a hot loaf of delicious, home-made bread.

Wheat Breeding

Most plants are hermaphrodite, in that they have both sexes in one plant, and usually in one flower. The male sex organs are the anthers, which produce pollen, and

the female organs are the styles, which receive pollen. Each pollen cell grows into the style and mingles its chromosomes with those of the female sex cell. Both the male and female sex cells (or gametes) carry a single set of chromosomes, and they are known as haploid. When they fuse, the resulting embryo has two sets of chromosomes, are it is known as diploid. However, strange things can happen with plants and their chromosomes. Pasta wheat, for example has four sets of chromosomes, and it is known as a tetraploid. Bread wheat, on the other hand, has six sets of chromosomes, and it is known as a hexaploid. These freaks occurred as the result of accidental hybridisation during domestication and, because the freaks were valuable to people, they were kept and cultivated.

Most plants are fertilised sexually by a process of cross-pollination. That is, each female sex cell is fertilised with a pollen cell coming from a different plant. The mechanisms that have evolved to guarantee cross-fertilisation are both numerous and ingenious, and they include insects and wind. These mechanisms produce the variability that is essential to the process of evolution.

However, some plants are self-pollinated. That is, the female sex cell is fertilised with pollen from the same plant, and usually from the same flower. This happens with plants that are annuals, and that survive the dormant season exclusively as seed. There are no tubers, bulbs, corms, or other survival mechanisms. Consequently, self-pollinating species must guarantee seed production if they are to survive at all. Otherwise there might be a freak season that prevents pollination and the species would be decimated, if not destroyed.

Self-pollination has an obvious disadvantage in that it prevents sexual recombination and the variation that is essential for evolution. For this reason, most self-pollinated plants have a small amount of cross-pollination in order to maintain variation. Wheat is a self-pollinated species, and this has considerable agricultural

significance because variation in crops is a nuisance. If plants do not "breed true", valuable agricultural characteristics can be quickly lost. This problem was solved by a Danish scientist, W.L. Johannsen, who discovered the pure line. He showed that, if you self-pollinate a single plant, and its progeny, for about six generations, you achieve genetic uniformity, and there is no further variation in the progeny. It was this kind of genetic line that Johannsen called the pure line, and this kind of genetic uniformity is now known as homozygosity.

Traditionally, wheat was cultivated as a landrace. That is, it was a mixture of many different lines, most of which were homozygous. However, a small amount of cross-pollination within the landrace would maintain the variability over long periods of historical time. The trouble with landraces is that they tend to averages. They have an average yield of a crop product which has an average quality. And, being mixtures, landraces produce many different wheat grains of differing size and strength. This makes both milling and baking rather difficult.

All modern wheats are pure lines. This means that they breed true, and valuable agricultural characteristics are preserved. However, there are disadvantages to this practice. One is a loss of biodiversity. Another is the difficulty of using vertical resistance (Chapter 2) which is liable to break down to new races of pests and diseases. If a single pure line is being grown over a large area, the loss of resistance can be very damaging.

The Green Revolution

The green revolution was initiated by Norman Borlaug who, as already mentioned (Chapter 2), was a pupil of E.C. Stakman. And, at first sight, his achievement was a vindication of the Stakman school of thought, and of vertical resistance. In fact, it was not a vindication but, by its very success, it prolonged this

erroneous school of thought unnecessarily. The new “miracle” varieties of both wheat and rice had vertical resistances to a number of important parasites. And the failures of these resistances have led to many difficult problems which would not have occurred, had the breeders used horizontal resistance.

However, there can be no question that the green revolution was immensely successful. In terms of increasing the carrying capacity of our environment, the green revolution was probably equivalent to the mechanisation of wheat harvesting by the invention of the mechanical reaper. In other words, it was one of the most important technical advances since the dawn of agriculture.

The green revolution, in both wheat and rice, was based on short stems. These so-called dwarf varieties of wheat and rice could be given large doses of fertiliser without danger of “lodging”. That is, the plants would not be blown over when wet in a storm. When cereal crops have been flattened in a storm, they are difficult, if not impossible, to harvest. For this reason, farmers had to be very careful not to put too much fertiliser on the old, tall varieties. But plants need fertiliser if they are to yield well. This danger of lodging was a major bottle-neck in the production of the world’s two most important food crops. And this bottle-neck was eliminated by the short straw of the green revolution.

The green revolution also coincided with a period of cheap fertiliser. Artificial nitrogenous fertilisers are made by combining atmospheric nitrogen with hydrogen to form ammonia, which is then further elaborated into nitrogenous compounds that are suitable as plant nutrients. It just so happens that this process is closely similar to the manufacture of explosives and, at the end of World War II, the world had a huge surplus of unwanted explosives factories. These factories could be used for making either explosives or fertilisers, but little else. The world also had a thirty year period of very cheap oil, and large amounts of heat are required for making ammonia from

atmospheric nitrogen. Nitrogenous fertilisers were consequently cheap in those days, and they could be used very effectively with the dwarf wheats and rices.

By the 1950s, the world population was completing its second doubling this century. It is a terrifying thought that the forty million people killed during World War II made little difference to this over-population problem. What is a mere forty million out of three billion? By the 1950s also, the world food shortage was becoming serious. The green revolution solved that shortage, at least for the time being. It saved millions of people from starvation, and at least a billion people from malnutrition. Remember that mother of seven, in the famine relief camp in Ethiopia (Chapter 1). In 1970, they gave Norman Borlaug the Nobel Prize for Peace. It was possibly the most richly deserved peace prize ever awarded.

Chapter Seven

Rice

Rice is to Asia, as wheat is to Europe. Just as the whole of western culture derives ultimately from the domestication of wheat, so Oriental culture derives from the domestication of rice. It is perhaps worth remembering also that, for most of history, the culture of China was consistently more advanced than the culture of Europe. It was only with the industrial revolution that the culture of the Occident overtook that of the Orient. It is worth remembering also that, for most of history, rice was quite the most important crop in the world. It was only with the opening of the North American prairies, and the mechanization of agriculture, that wheat became marginally more important than rice.

Rice was also responsible for the many civilisations of tropical Asia, of which the Khmer of Cambodia is possibly the best known today. This kingdom had about one million people, and its temple complex at Angkor has temples so large that they are called “temple mountains”. This incredible city was built on the edge of a lake called *Tonle Sap*, which flooded during the rains, and then drained into the Mekong River, providing rich mud flats for rice cultivation (Chapter 3).

In Chapter 9, it is mentioned that the ancient Austronesians took rice from Indonesia to Madagascar, by sailing directly across the Indian Ocean, some three thousand years ago. However, although they cultivate paddy rice, the people of Madagascar never produced a great civilisation, comparable to those of, say, China, Cambodia, Japan, and India. The reason is that Madagascar, which is sometimes called the largest island in the world, has incredibly poor soils that are mostly quite

unfit for agriculture. To this day, rice can be cultivated only in the rather rare valley bottoms, which have both the necessary water and good, alluvial soils. This limitation has kept the population of Madagascar low and, although these charming people are very cultured, and very civilised, they have not produced cities comparable with those of China.

Rice is the only crop (apart from water cress) that is a water plant, grown in ponds. In English, these ponds are often called ‘paddies’, somewhat inaccurately, as the Malay word *padi* refers to the rice plant, rather than the pond. The rice ponds are quite shallow, and the rice plant is firmly rooted in mud at the bottom. In areas of high rainfall, the ponds are filled by rain, and any excess of water is allowed to drain downhill, from pond to pond. In river valleys, however, the ponds are usually filled from irrigation ditches, and these have to be rigidly controlled in a somewhat strict society.

With an abundance of water, rice is capable of very high yields. Given a good rice variety, and good growing conditions, a rice crop will yield up to twelve tons of grain per hectare. And, because rice is gown in the tropics, where there is no winter, it is usually possible to grow two crops each year. In some areas, and with some rice varieties, they can even grow three crops in one year. By way of comparison, the North American prairies produce only two tons of wheat per hectare, and can grow only one crop each year. At its best, therefore, rice can yield 12-18 times the amount of food produced per hectare in the American prairies. This explains why the countries of the Far East have such high population densities. It also explains why the cultivation of other crops is very limited, and occupies relatively little land. Alternative crops in rice-growing countries are mostly spices, such as chillies, ginger, cardamom, cinnamon, and black pepper. There are also some tree fruits, such as citrus and mango. But other staples (e.g. maize, cassava, sweet potato, yams, etc.) are

usually absent, because they cannot compete with rice in terms of taste or productivity. And animal husbandry is often confined to stall-fed working animals, such as water buffalo, and meat animals, such as pigs and poultry, that are confined in pens.

In addition to being such an important crop, rice is also an excellent food. Boiled rice is digested more quickly, and more easily, than any other food. For this reason, it is often prescribed for invalids who are able to eat little else. High quality cooked rice is light and fluffy, and it makes an excellent basis for innumerable dishes in the justly famous cuisines of India, China, Indonesia, Vietnam, and Japan. Unlike wheat, however, rice contains no gluten and it could not be used for making bread.

Although rice is beyond question an Old World crop, it was domesticated twice, with a different species being used each time, in the manner of cotton (Chapter 16) and yams (Chapter 2). One domestication was in West Africa and this rice is *Oryza glaberrima*. The other domestication was in Asia, and it produced *Oryza sativa*, which has become the main rice of the world, and has largely supplanted the native rice in West Africa.

It has already been mentioned (Chapter 3) that rice is one of the three basic staples of the world. This comment referred to Asian rice, which has much higher yields than African rice. Asian rice produced all the great civilisations of the Far East. But African rice was poor stuff in comparison, and was no more able to generate a great civilisation than the other indigenous cereals of Africa, such as millets and sorghum. Equally, the so-called “wild rice” (*Zizania acquatica*) of North America is not a true rice at all. It is another example of an indigenous grass which was not sufficiently productive to become an important staple, or to produce a major civilisation. Indeed, as its name implies, wild rice is not even cultivated and, traditionally, it was merely collected by hunter gatherers. It is these minor cereals

which, by their very lack of importance, emphasise the cardinal roles of wheat, Asian rice, and maize, in human cultural development.

Both the time and the place of domestication of Asian rice are uncertain, and it is probable that the domestication was a diffuse one. That is, the wild progenitors were taken into cultivation repeatedly, in many different areas, over a long period of time.

The oldest archaeological record of rice is from Thailand, and is in the form of pottery which has rice grain imprints on it, dating from 3,500 BC. There is a wealth of historical and archaeological evidence of rice from China, going back to 3,250 BC. The earliest archaeological evidence from India is 2,500 BC. The earliest record of rice in Japan is from the Yayoi culture which has pottery that shows marks of rice husks. This indicates that rice cultivation occurred in Japan at least as early as 250 BC. Archaeological remains of paddy fields and irrigation canals of this period have also been found in Japan, and the rice culture of that period was clearly a well developed one.

The diffuse domestication of rice apparently occurred in the area of Burma, and northern Thailand, Laos, and Vietnam, extending eastward to Southern China, and westward to Bangladesh, and north eastern India. The cultivation of this domesticated rice apparently spread slowly from this sub-tropical area to the Yellow River of China, where the very different, temperate strains of rice were developed. Rice undoubtedly contributed to the development of the Chinese culture, which was one of the original major civilizations, the others being the Indus Valley, the Tigris-Euphrates, and the Nile, which were all based on wheat, and the Central and South American civilisations, which were all based on maize.

The diffuse domestication may also explain why the spread of rice culture did not lead to the spread of a single family of languages, as happened with wheat. There

was no wave of advance, because rice culture started independently in various different areas. In addition, the introduction of rice growing to a new area, such as north China, was probably made by the people already inhabiting that area. This was because these people were not hunter-gatherers. They already had an agriculture based on millets. Their population density was probably too high to permit a wave of advance of rice cultivators from the south to displace them. In a similar manner, the use of rice spread from northern China to Korea and Japan.

However, there probably was a wave of advance into the Philippines and Indonesia. These islands are likely to have been inhabited by dark skinned people closely related to either the Melanesians, or to the indigenous inhabitants of Papua New Guinea and Australia. This wave of advance would have been made by Austronesians (Chapter 9) coming originally from Taiwan. This subject of Austronesian exploration is discussed in more detail in Chapter 9.

Like soya and potato (Chapter 11), rice is sensitive to day-length, and the northward spread of this crop depended on the development of new types of rice with altered day-length requirements. This domestication produced several subspecies, which have been named after their areas of cultivation. These subspecies are *japonica*, *indica*, and *javanica*. Cultivation of subspecies *indica* is confined to the tropics. Subspecies *japonica* is cultivated in temperate climates with long summer days. Traditionally, it was cultivated in North China and Japan, but it is now cultivated also in Europe, California, Australia, and other temperate areas. Subspecies *javanica* is equatorial.

During World War II, the Japanese military apparently did not know about these different subspecies, and they insisted, against local advice, on large acreages in the Philippines and Indonesia being planted to Japanese varieties. A serious food

shortage resulted when these long-day rices refused to flower in the short-day climate of these tropical countries.

The process of domestication produced many changes in the rice plant. The plant became larger, and capable of producing considerably increased numbers of heavier grains. As with wheat (Chapter 7), the ‘shattering’ character was lost, and domesticated rice no longer sheds it own seed. Without this character, the harvesting of rice would be all but impossible. The amount of cross-pollination also decreased, and rice became a self-pollinating crop in which pure lines (Chapter 2) are both feasible and common.

There are so many different varieties of rice that no one has ever counted or catalogued them all. A conservative estimate is ten thousand varieties, actually being cultivated throughout the world, but the true figure may well be double this number. This large number of varieties results from both the great age of the rice crop, and the huge area of cultivation for most of its long history. Traditionally, rice is harvested by hand, by cutting off one head at a time. This procedure greatly improves the chances of a markedly different, and superior, head being recognised and retained for seed.

A head of rice is quite different from a head of wheat. Indeed, it resembles a head of oats more closely than any other cereal. Each rice floret, and each ripened grain, is well separated from every other grain by a thin and flexible stalk. A head of rice contains between one and five hundred grains, held on a large number of stalks which branch, and branch again, in what is called, botanically, a panicle.

Rice also has the growth habit known as tillering. Each seed that is planted produces a stem, with a head of rice grains at the end of it. But it also produces tillers, which are side stems growing from buds at the base of the main stem. The tillers may themselves produce tillers. One rice seed thus produces many rice stems, each with a head of rice with several hundred grains in it. This is why rice is such a productive

crop, and why it justifies so much labour, with transplanting by hand, and very careful spacing of the plants. An important aspect of the domestication of rice was that all the tillers of cultivated rice mature at the same time as the main stem. This makes harvesting very much easier.

It is this very high productivity that is responsible for some of the characteristics of rice growing societies. The key feature of all these societies is their very high human population density. Rice cultivators have probably increased the carrying capacity of their environment to the absolute limit for a pre-industrial society. And the age of these rice-growing societies has ensured that the human populations have been maximal for centuries. As a consequence, rice growing people usually have a social organisation that is highly complex, and very strictly regulated by convention and ritual within a rigid social hierarchy. The control is often achieved by religious injunction, rather than by government. There are then many priests, many temples, and many religious ceremonies. This tight control has apparently developed over many human generations, largely on the basis learning by experience. All the control, and all the ritual, is aimed ultimately at achieving the maximum production of rice. Any shortfall means that people will go hungry. And anything in the nature of disputes, civil disturbances, or non-conformity, could jeopardise the rice production, and threaten a famine.

A high population density can have many secondary effects. There is always a shortage of land. Every suitable land surface is then devoted to rice paddies. There are few roads, and the pathways between the paddies are minimal. The houses are small, and crowded together. There are few trees and, for this reason, there is a chronic shortage of fuel for cooking. Many of the cuisines based on rice are often derived from cooking methods that save fuel. The ‘stir fry’ method, for example,

involves very fast cooking of small pieces of food, using scarce fuel that has been imported from an area where rice cannot be grown.

A special feature of paddy rice is that this aquatic cultivation compels the use of terraces in which the water is held in place by walls or ‘bunds’. This system just happens to provide the perfect method of controlling soil erosion, and this explains why many rice growing cultures are both ancient and still continuing. Many of the equally ancient, but rainfed, agricultures declined long ago because of soil erosion problems. Modern Greece lacks much of the soil that was available to the ancient Greeks. The cedars of Lebanon were famous in Biblical times but, today, most of the soil that supported those trees has disappeared.

The very high multiplication rate of rice greatly assists plant breeding, because a breeder need make only a few hand pollinations, followed by a multiplication generation, and he will then have hundreds of seeds for screening. Equally, a potential new variety may consist of only a few hundred seeds, but it can be multiplied into many tons of seed very quickly. This seed multiplication is normally combined with field evaluation trials, in which many rice lines, which constitute potential new varieties, are compared. With each generation of trials, the number of potential varieties is reduced, and the amount of seed of the remaining lines is increased. By the time the final selections are made, each consists of considerable quantities of seed.

When grown in the traditional way of small farmers in Asia, rice is a labour-intensive crop requiring up to one thousand man-hours of work per hectare. The land must be tilled and flooded, the seeds must be germinated in a separate seedbed, and then transplanted into the field. And the crop is weeded, harvested, threshed, and winnowed by hand. All this labour is justified for the most productive crop in the world.

At the other extreme, rice cultivation in the United States, mainly in California, is highly mechanized, and requires less than fifty man-hours per hectare. This indicates just how important mechanisation has been in the development of modern agriculture, and the liberation of yet more people from food procurement.

In California, the large fields are levelled very accurately with huge machines called ‘land planes’, controlled by laser beams. The land is flooded, and then drained, to leave a soft mud. The seed is sown from an aircraft and its fall plunges it into the mud where it germinates. Once the seed is rooted, and can no longer float, the land is flooded again. All land preparation, fertilizing, and harvesting is highly mechanized, and all weeding and pest control is done by spraying, usually from aircraft. Because of the dry atmosphere, the rice has few pests or diseases, and it has some of the highest yields in the world. These Californian rice crops apparently approach the ultimate limit of crop production.

Newly harvested rice is called ‘rough’ rice, and it is enclosed in husks. Threshing removes the husk, and produces ‘brown rice’. In the old days, threshing was done by pounding the grain, and then winnowing it, by tossing it into the wind. The heavy grain would fall on to a mat, and the light husks would be blown away. Nowadays, most small farmers have a simple, hand operated threshing machine which also contains a fan for winnowing the rice.

The brown rice can be cooked and eaten but most people prefer to eat white rice, from which the bran has been removed by milling. White rice is often polished, and a coating of glucose and talc may be applied to make the grain glossy. Brown rice is more nutritious because the bran contains eight percent protein, all the main B vitamins, iron and calcium.

When a major proportion of the diet consists of white rice, the thiamine deficiency leads to a disease called beri-beri. This condition has been known in the

Orient for at least a thousand years, but its cause was not discovered until the Japanese navy eliminated beri-beri among its sailors by improving their diet with other foods.

Some of the nutritional deficiencies of polished rice can be overcome by a process called ‘parboiling’. Parboiled rice is partially boiled, and then dried, prior to milling, and this drives many of the nutrients from the bran into the grain itself. Rice can also be enriched with added minerals and vitamins. Combined with a more varied diet, these measures have largely eliminated beri-beri from the world.

The by-products of rice milling are used either as animal feed or for a variety of industrial purposes. Oil can be extracted from the bran, and broken grain is used for starch production, milling into rice flour, brewing and distilling. The husks can be used for fuel, packing, mulch, and as feedstock in the chemical industry. Rice straw can be used for various purposes such as packing, thatch, weaving into mats, stuffing mattresses, and making brooms.

One of the few contributions to rice utilization which came from the West was the ‘puffing gun’, which was invented in the United States early this century. This machine produces puffed rice, otherwise known as rice crispies. It works by heating cooked and sweetened rice grains, under a pressure of about ten atmospheres, in a pressure chamber. The pressure is released very suddenly, and the water in the rice grains changes into steam, causing the grains to expand in a manner very similar to popcorn (Chapter 8). The expanded grains are then dried and toasted in hot air to produce the popular breakfast cereal.

Once Norman Borlaug had shown the world that dwarf wheat (Chapter 6) could increase yields by being given high applications of nitrogen fertilizer, without danger of lodging, scientists realized that they could do the same with rice. The Rockefeller Foundation, which had been responsible for financing Borlaug's wheat

research in Mexico, and the Ford Foundation, then created the International Rice Research Institute, at Los Baños, near Manila, in the Philippines. This Institute very quickly produced new dwarf varieties of rice, known as the "miracle" rice varieties. The most famous of them was called IR.8, and the scientist who bred it was Peter Jennings.

IR.8 was produced by crossing a tall, vigorous variety from Indonesia with a dwarf variety from Taiwan. Its yield is twice that of most local varieties because, being a dwarf, it can be given these high applications of fertilizer without lodging. Because it is also an early maturing variety, it often allows an additional crop each year. It was this variety, more than any other, which solved the problem of chronic rice shortages in the Far East.

The effect of the miracle rices was that many countries of Southeast Asia changed from being importers of rice to being self-sufficient in rice. Some of them even became exporters of rice. With about half the world's population dependent on rice, the miracle rices may be said to have saved at least one billion people from malnutrition and, possibly, starvation. These new rice varieties have thus produced a highly significant increase in the carrying capacity of the human environment. And they did it by the very simple expedient of short stems.

Inevitably, problems arose as a result of the green revolution in rice. The miracle rices are pure lines and, by replacing landraces, their use has greatly reduced genetic diversity within rice crops. Because a single new miracle variety was liable to be grown over vast acreages, the genetic diversity *between* rice crops was also reduced. The resulting crop uniformity is dangerous, and was responsible for some nasty epidemics of pests and diseases in the new varieties. In India, for example, a bacterial leaf blight, and a virus disease called *Tungro*, entirely prevented the cultivation of some of the miracle varieties.

Another difficulty with the miracle rices is that some of their resistance to pests and diseases is vertical resistance (Chapter 2) which is liable to fail when a new strain of the parasite appears. The resistance to both blast disease (*Pyricularia oryzae*), and an insect pest called the brown plant hopper (*Nilaparvata lugens*), has failed repeatedly for this reason, causing considerable losses, and distress, in the process. In order to maintain the high yields of the miracle varieties, subsistence farmers have had to begin using chemical pesticides for the first time ever, and this is a development to be deplored.

Under some systems of agriculture, rice can be an exceptionally useful rotation crop. The Punjab, for example, is a vast plain, now divided between India and Pakistan, which undergoes natural flooding each year from the melted snow of the Himalayas. Today, the area has one of the world's largest water control schemes with miles of canals which both drain off, and store, excess water in the summer, and distribute it for irrigation, in the winter. The farmers practice an excellent rotation of rice in the summer and wheat in the winter. The flooded rice fields kill off all the pests, diseases, and weeds of the wheat. And the dry wheat fields kill off all the water-loving pests, diseases, and weeds of the rice.

Chapter Eight

Maize

The word 'corn' is an old English term for a small hard particle, such as a grain of salt or sand, or a painful callous in the skin. Nowadays, it is used most commonly to describe small seeds, also called "grain", and it traditionally refers to the edible product of any cereal, such as wheat, rye, barley or oats. In its original sense, the term also described other plant grains, such as grain legumes (i.e., peas, beans, and lentils) and buckwheat. The word also appears in such terms as peppercorn, corn chandler (i.e., corn merchant), corncrake (a bird), cornflower (a bright blue, wild flower), corn cockle (a wild pink), corn land, and corn laws. The term corned beef, however, refers to the cooking of beef with salt. Beef that is boiled with salt retains its red colour.

When Columbus discovered the New World, his wishful thinking convinced him that he had discovered India, and he described many of the things and peoples of the New World in terms of India. The Arawak people of Cuba called their staple diet *mahiz*, and this Arawak name was later corrupted to maize. But, because of Columbus, this cereal (*Zea mais*) became known as "Indian corn".

The word 'corn' is often given a special local meaning describing the predominant cereal of the area. In England, for example, corn usually means wheat. In Scotland, it commonly means oats, and so on. When early English-speaking settlers began cultivating Indian corn in North America, they used the generic term 'corn' to describe this maize. To this day, maize is called corn in North America, and

the maize growing area is known as the corn belt. But this is local usage, and the crop is still called maize in all other countries, and in all other languages.

As we saw in Chapter 3, great civilizations can develop only if there is a settled population with a stable agriculture. In its turn, this requires the possession of at least one of the three staples, wheat, rice, or maize. Local cultures, including the creation of beautiful cave paintings and basket work, obviously develop in hunter gatherer societies, and among nomadic herdsmen. But great civilizations, involving the growth of cities, with high population densities, systems of law and order, and the wide development of arts and sciences, all require a system of food production that is both efficient and reliable, and a food product that can be stored.

Without exception, the great civilizations of pre-Columbian America were all based on maize, supplemented with haricot beans for protein, and squash for Vitamins. This is not to say that the possession of maize would automatically lead to a great civilization. But the fact remains that any people in the New World who did not possess this crop, and the knowledge of cultivating it, did not develop an important civilization. The indigenous peoples of temperate North and South America, as well as the people of the Amazon rain forest, where maize grows only poorly, never progressed beyond the village stage of cultural development, and many remained in the hunter gatherer stage. In contrast, the Olmecs, Mayas, Aztecs, Incas, and other peoples of Central and South America, who did possess maize, developed great cities and nations comparable with those of a similar date in other continents.

Many people do not appreciate just how advanced these civilisations really were, for the simple reason that they were destroyed some five hundred years ago. The main agents of destruction were the re-encounter human diseases, which were carried by resistant Europeans, and which decimated the susceptible, indigenous populations. The survivors were cruelly exploited by Spain for some three hundred

years. It was only when Napoleon conquered Spain, and the Spanish monarchy disappeared, that the various countries of Latin America found themselves free and independent. And it is only recently that their indigenous cultures have been properly studied and appreciated.

The most important example of Meso-American culture is undoubtedly Teotihuacan, which means “City of the Gods” in the Aztec language. This city was ancient history to the Toltecs when Europe was still in the Dark Ages. The building of Teotihuacan commenced about 150 BC. Seven hundred years later, it was at its peak, with a population of 150,000 people. It was laid out on a grid plan, like a modern American city, and it eventually covered an area of more than nine square miles. The main ‘street’ was four miles long, and forty yards wide. Another street, of equal length, bisected it at right angles. Temples were built on the tops of two pyramids which were comparable in size to the pyramids of Egypt, indicating the organisation and control of very large gangs of *corvée* labour.

Little is known about the people who built Teotihuacan. We do not even know their name, or their language. But they had a profound influence on the Maya peoples to the South, and on the Toltecs, and later on the Aztecs. The cultural influence of the people of Teotihuacan on pre-Columbian Central America is comparable to the influence of the ancient Greeks on Western civilization.

When Cortés reached the Valley of Mexico, he found a double city, Tenochtitlan and Tlatelolco, with about one quarter of a million inhabitants. This was about five times the size of London as it was at that time. He also found many other cities in Central Mexico, with large populations, and the entire Aztec Empire has been estimated to have had a population of some ten million people.

None of this would have been possible without maize which was domesticated in about 5000 BC. The age of this domestication has been proved by archaeological

relics, but there is also circumstantial evidence indicating an ancient domestication. Maize is so altered from its wild progenitors that these have proved difficult to identify. Secondly, maize cobs are completely enclosed in modified leaves, or bracts, and the plant cannot disperse its seeds. Obviously, such a self-eliminating character could never evolve in a wild plant. Thirdly, there is enormous variation within maize in its area of origin.

The people who first domesticated maize obviously managed to preserve it, to improve it, and to ensure that it increased and multiplied. And their descendants have been cultivating it, and further improving it by artificial selection, ever since. And, from its centre of origin, it spread to South America and was responsible for the various civilisations of the western seaboard.

All of these civilisations were later conquered by the Incas, who had a strict military hierarchy, and a rigidly controlled society that was reminiscent of the ancient Romans. The Inca king was an absolute monarch, believed to be a direct descendant of their sun-god. For purposes of government, their empire was divided into four quarters; each quarter divided into provinces, and each province into communities. They had the most advanced, and the most rigidly controlled agriculture of the pre-Columbian New World. They worked with a strict calendar, doing their ploughing in August, their sowing in September, and their harvesting in May. The *yanca ayllu* or "worthless ones" were at the bottom of the social scale and the equivalent of serfs. They first had to work the fields belonging to the priests, then those belonging to the king and, finally, they were permitted to work their own communal plots. This society was every bit as authoritarian as Karl Wittfogel's hydraulic cultures (Chapter 4).

Maize was also spreading into North America where it was responsible for cities and cultures such as the Hohokam, Mogollan, and Anasazi.

And then the Europeans came, and Columbus took maize to Spain. Soon after, the Portuguese took it to Africa and to various lands of the Indian Ocean. There was then a major increase in the carrying capacity of these environments. The adoption of maize as a basic food occurred only as the need arose, because most people are conservative in their food preferences. They are likely to adopt a new food only if the need is very pressing. In southern Europe, for example, maize became the staple diet of the poor, who could not afford wheat products such as bread or *pasta*. But this happened only during the seventeenth century, following an unusually bad series of wars and plague.

The introduction of both maize and potatoes led to a human population explosion in Europe. The population was 100 million in the mid-seventeenth century. By 1900, the population of Europe had quadrupled to 400 million. The industrial revolution would have been impossible without this population increase because too high a proportion of the people would have been tied to the land, and to food production. Similarly, the introduction of maize, sweet potatoes, and cassava led to a human population explosion in Africa. And the slave trade would scarcely have been possible without this population increase.

Poor people began to depend on maize so heavily that there was a very real danger of diet deficiency problems. An excessive reliance on maize leads to vitamin deficiency problems generally known by the Italian name of *pellagra*, which means "rough skin". This problem caused endless suffering and many deaths for a couple of centuries. It was not solved until the 1920s when Joseph Goldberger, an American doctor, showed that it was a vitamin deficiency resulting from an excessive dependency on maize. In this sense, it can be compared to beri-beri, which results from an excessive dependency on white rice (Chapter 7), and scurvy, which results

from a deficiency of vitamin C (Chapter 9). In this sense also, the potato is a more complete food that maize. The poor of northern Europe did not suffer from *pellagra*.

The first maize was very primitive, with small cobs, and small grains that were enclosed in hard shells. It was far superior to its nearest relative, the wild teosinte, however. Subsequent domestication led to large cobs, and large grains, with the hard shells reduced to harmless relics, surrounding the base of the seed. In this sense, maize is more highly domesticated than wheat, because its grains are non-shedding, they are free of husks, and they are well protected by a sheath. Maize also yields considerably more food than wheat per unit area of crop.

The most primitive type of maize, which is no longer cultivated, is called ‘pod corn’ and has each seed enclosed in husks. ‘Popcorn’ is also believed to be a primitive type with small, hard grains. It is of very minor agricultural value, but it is of social interest as a popular confection associated mainly with cinemas and movies. The hard grains are heated until the water inside them reaches boiling point, and the grain then bursts explosively to produce the well known, fluffy, popcorn of commerce.

‘Flint’ maize has relatively small grains that are hard, with rounded ends. This was the maize of pre-Columbian North America, and it was being cultivated by some of the Amerindians of the Northeast, when the Pilgrim Fathers first arrived from Europe. Many grain colours occur in flint maize, and this type is one of the hardiest forms, suitable for cultivation in high latitudes, and high altitudes. It is an early maturing type, and the small grains are suitable for feeding whole to chickens.

Dent maize has soft, starchy grains which shrink on ripening to produce a characteristic dent in the end of the seed. This is the maize of the corn belt in the United States. Flour corn is a related type which has a high proportion of soft starch, and is easily milled to produce corn flour. Sweet corn is another variant which

contains an abnormally high sugar content, and is harvested unripe for eating as ‘corn on the cob’. Other types of minor importance occur, and the variation within them is considerable.

Maize is an ideal food for subsistence farmers in the tropics and subtropics. It is a high yielding crop which produces food in a very convenient and compact form, that is easy to harvest and transport. Its return per man-hour of labour is one of the highest of any food crop. The plants can be grown, and the cobs can be harvested, and consumed, over an extended period of overlapping crops and seasons, and they are well protected from birds and bad weather by their sheaths.

In much of Africa, maize has replaced the traditional, indigenous cereals, such as sorghum and millets, which are now grown only in areas that are too dry for maize. A further disadvantage of these older cereals is that they are plagued by seed-eating birds, called *Quellea*, which occur in large flocks, often containing several million birds.

Each *Quellea* bird eats its own weight in seed each day, and a flock of birds can entirely destroy a farmer’s cereal crop in a few hours. In the wild, these birds eat the seeds of wild grasses. But, with the advent of agriculture, and the widespread cultivation of cereals whose seeds are unprotected by a sheath, such as sorghum, millets, wheat, rice, oats, and barley, these birds have become a major pest. They now occur in their hundreds of millions throughout tropical Africa. The fact that maize is protected with a sheath is one of the reasons for its popularity in this part of the world.

In Kenya, they used to have a bird control specialist whose function was to kill as many birds as possible. The birds would usually roost at night in a clump of gum trees (*Eucalyptus* spp.). The bird man would then place about ten, open, forty-gallon drums of kerosene in the clump of trees. He would sink a stick of dynamite into each

drum, and all the dynamite would be linked with instantaneous fuse. He would then attach a piece of slow fuse to the fast fuse, light it, and run like hell. It should be remembered that this was after dark, and large crowds had gathered to see the fun. The resulting bang would instantly kill about three million birds in one tremendous flash and heat blast. It would also strip the trees of all their leaves and smaller branches. The birds would have all their feathers burnt off, and they would be cooked, providing an unusual fast food outlet for the local people, many of whom had lost their cereal crops. So there was a certain poetic justice in this crude and clumsy method of bird control.

The method was also expensive and somewhat dangerous. It was finally abandoned when an explosion was set off rather too close to a country club. Windows were broken and two costly chandeliers came crashing to the floor. Fortunately, no one was injured, but it was thought advisable to transfer the bird specialist to the less dangerous activity of inspecting potatoes.

The next method of controlling the birds was to spray them with a chemical called parathion. This method was very effective but it did have certain disadvantages. Parathion had been developed as a poison gas during World War II, and it was very dangerous, both to the operators, and to surrounding farmers, particularly as the farmers were under the impression that they could eat the poisoned birds.

At this point, a very bright scientist was asked to investigate the problem. He discovered that the birds were very sensitive to cold. He found that, if they were sprayed with plain water containing a little dish-washing detergent, they would be wetted to the skin and they would then die of hypothermia. This is the method used to this day. Some water, a little detergent, and several million birds are cheaply

destroyed without an explosion, without poison, without danger, without damage to the trees, and producing meat that is safe to eat. However, this is a digression.

The husks of the maize cob provide complete protection against *Quellea* but, quite apart from this, most people in Africa now prefer maize dishes to those prepared from sorghum and millet. However, in those areas of Asia where rice is a traditional crop, maize has made less headway, and rice remains the preferred food, and the second most important food crop in the world, after wheat.

Subsistence farmers eat maize in a variety of ways. The most popular in Africa is to pound the grains into a meal, which is mixed with water, and is then either boiled as a thick porridge, or baked, or fried. Alternatively, the grain is cooked whole, either by roasting, or boiling. A popular method is to roast the entire cob over an open fire. In Latin America, a maize dough is cooked to make *tortillas*, and *amales* are prepared by steaming the dough. However, maize does not contain any gluten and, until very recently (Chapter 6), it could not be used for making leavened bread.

In the industrial nations, the commonest use of maize as human food is in cornflakes, eaten as a breakfast cereal. Cornflakes were developed in Battle Creek, Michigan, by John Harvey Kellogg (1852-1943), who was a medical doctor, and director of the Battle Creek Sanitarium. He was a vegetarian, specializing in health foods, and his cornflakes inspired his brother, William Keith Kellogg (1860-1952) to form the W.K. Kellogg cereal company in 1906. One of John Kellogg's patients at the Battle Creek Sanitarium was C.W. Post, who also founded a breakfast cereal company whose corn flakes were known as ‘post toasties’.

In industrial countries, the grains of sweet corn are also eaten directly, as human food. They are usually eaten as a fresh vegetable, but they can also be preserved, either in cans or, more commonly these days, by deep freezing. Maize starch is known as corn flour, and it is often used as a substitute for egg custard, and

to make moulded puddings called *blanc mange* or 'shape'. Corn flour also has many other uses, both culinary and industrial, as a thickener and stabiliser.

Maize is fermented to make native beer in most countries where the crop is grown on a subsistence basis. In the United States, Bourbon whisky is made by distilling fermented maize. Several hundred industrial products and byproducts are obtained from the maize crop. The grains can be milled either dry or wet. Dry milling removes the bran and the embryo, and the coarsely crushed endosperm is known as 'grits'. Wet milling involves soaking the entire grain in an alkaline solution. The skin, or bran, is loosened and washed free, and the remaining endosperm is called 'hominy'.

Unless it is fed directly to livestock, industrial maize is processed in a special factory. The main product is starch which constitutes sixty five percent of the total weight. This starch is either dried, and sold as such, or it can be converted into 'corn sugar', or dextrose. The starch can also be fermented into alcohol, or used as industrial feedstock in the production of various organic chemicals. About three percent of the grain is oil, which is extracted by dissolving it in liquid hexane, which is then evaporated off, and re-used. The remaining thirty percent of the grain is usually prepared as animal feed but various other chemicals can be derived from it.

The green maize plant makes excellent fodder for cattle and it is grown for this purpose particularly in the high latitudes of countries such as Canada and Britain. An alternative use is in the preparation of silage, which is a method of preserving green fodder without drying. The green material is chopped and put into an airtight silo, or huge plastic bags, where it undergoes a chemical fermentation that produces sufficient heat, both to sterilize the silage, and to stop the fermentation process. More recently, some excellent plant breeding has produced early maturing maize varieties

which will produce a crop of grain in the short, cool summers of high latitude countries such as Britain and Canada.

But, above all, maize, or corn, is the crop of the United States where, for many years, it has been the most important crop of all. The corn belt of the United States includes Iowa and parts of Illinois, Indiana, Ohio, Missouri, Kansas, Nebraska, South Dakota and Minnesota. This corn belt produces more than half the world's total maize, averaging some seven trillion bushels annually. China is the second largest producer with some two trillion bushels annually.

Part Three

Other Crops that Shaped History

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Chapter Nine

Coconuts

In the tropics, coconuts are often described as God's gift to man because they provide far more than refreshing snacks and drinks. Tropical people often rely on the coconut palm for many, indeed most, of their essential requirements.

They use the dried seed shells for cups and containers, the oil for illumination, cooking, and skin balm, the husk fibres, known as coir, for matting, brooms and brushes, the plaited leaves for hats, mats, and thatch, the palm trunks for beams, and timber, and the sap for fermenting into an alcoholic toddy. Even the growing point, the apical meristem, provides a tasty, nutty vegetable, which is eaten raw, and is known as millionaire's salad, because an entire palm must be felled in order to obtain it.

Coconuts evolved in Southeast Asia, in the general area of Malaysia and the Philippines. The undomesticated, wild type is a tall palm which grows about a foot each year, and attains heights of up to sixty feet. It bears about sixty large nuts each year. These nuts are well protected with a thick, fibrous husk which enables the nut to
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fall from the top of the palm to the ground without being damaged. The nut is heavy and, on rare occasions, people have even been killed by falling coconuts.

The natural habitat of coconuts is the sea shore, on the margin between beach sand and land vegetation. When coconuts fall to the ground, they either remain where they are, and germinate, or else they roll down the sloping beach to the sea. The thick husk permits the nuts to float, and they can survive for several months floating in sea water. This is a natural seed dispersal mechanism, and it explains why coconut palms occur typically along tropical sea shores. This dispersal mechanism successfully distributed coconuts throughout the tropical Indian Ocean, and to the many islands of the western Pacific. However, the floating nuts do not survive for ever, and the natural dispersal could not take the coconut round the Cape of Good Hope into the Atlantic. Nor could it carry coconuts to the eastern limits of the Pacific, and to the western shores of tropical America.

Domestication

H.C. Harries is the world authority on the evolution of coconuts. He has suggested that the early planters of coconuts would choose seeds from the palms that most closely fulfilled the functions of a modern soft drink dispensing machine. That is, they chose the smaller palms, with nuts that were closer to the ground, and easier to reach. And they chose palms with many nuts, and with nuts that had less husk. These would provide more frequent snacks and drinks, in containers which were easier to reach, and easier to open. The result of this domestication was a dwarf palm, with nuts smaller than the wild type, but which were easily collected, easily opened, and numerous. But, unlike the wild type, these nuts could not survive when floating on sea water, and they had no natural dispersal mechanism. They could be spread around the world only by people.

A tropical sea shore is an excellent environment for hunter-gatherers, because tropical reefs provide some of the richest and most reliable natural sources of animal protein to be found anywhere. But tropical sea shores have one grave disadvantage, particularly when they occur on small islands. Fresh water is scarce and, prior to a knowledge of wells, it was often entirely unavailable for long periods. The coconut solves this problem. Indeed, as we have seen, the coconut palm has been called humankind's first drink dispenser. In some ways, it is superior to modern soft drink machines, because the drinks are free, and they are of a particularly high quality. It is a very special experience to be thirsty in the tropics, and then to drink the milk of a freshly opened green coconut, straight out of the shell. And a *pina colada* made with fresh, green coconut milk has to be tasted to be believed.

Desert Islands

As we have seen (Chapter 1), our human ancestors was able to colonize most of the land surfaces of the world by *walking*, starting from their center of origin in Africa. This process was greatly facilitated by the ice age, and the retreat of the oceans into enormous polar ice caps, and glaciers that covered much of the cooler, temperate regions. This accumulation of ice lowered the sea level and exposed the land bridge of Beringia that links Asia with Alaska. Similarly, Australia could be reached with very short boat journeys when the sea level was low. This island continent was colonized by hunter-gatherers, long before the development of agriculture, at least 20,000 years ago, and possibly as much as 40,000 years ago.

The only habitable land that remained uncolonised by people consisted of remote islands that could be reached only by long sea journeys. It turns out that every remote island in both the Pacific and the Indian Oceans is populated by people who all speak the same family of languages. This is the Austronesian

(or Malayo-Polynesian) family of languages. It is centred on the islands of the Philippines and Indonesia, and it extends to Madagascar in the West, to Easter Island in the East, Hawaii in the North, and New Zealand in the South. It is, without question, the most widely dispersed family of languages, having spread halfway around the world. It is also indisputable that this language dispersal was made not by walking, but by *sailing*.

Ocean Travel

This language dispersal raises some interesting questions, because sailors in ancient times had four major problems. They had to navigate, in order to know where they were. They had to survive the danger of storms at sea. They had to have a supply of fresh drinking water. And, finally, they had to have a source of fresh fruit and vegetables if they were to avoid the problem of scurvy on long ocean journeys.

The ancient Egyptians were the first people recorded as having used boats. However, their boats were not seaworthy. Nor did they need to be, because they never left the Nile. These sailors had no need to navigate because their boats were confined to the narrow river in much the same way as a railway train is confined to its track. Ancient Egyptian sailors never ran short of drinking water because they were sailing on the stuff, and they could go ashore at any time, if there was a storm, or if they wanted fresh fruit or vegetables. The prevailing winds in Egypt are from the North, and these winds propelled their boats upstream. The river current carried them downstream.

No doubt as a result of Egyptian influence, sailing developed quite early in the Mediterranean. The Minoans and the Phoenicians were the most prominent of the early maritime peoples. They had boats that were much more seaworthy than the Egyptian. Nevertheless, they avoided storms by sailing only in the summer months,

and by keeping the refuge of land in sight whenever possible. Following the coastline was also their means of navigation, and the nearby land was their source of fresh water and food. They usually chose to go ashore at night, and to sail only during daylight. These sailors would often make a dash across open water in order to reach the more remote islands, such as Crete. But this was always considered a risky thing to do, and it never involved being more than a few hours out of sight of land.

The Phoenicians were more adventurous, and they sailed outside the Mediterranean. They sailed up the West coast of Europe, and they reached Britain, and the tin mines in Cornwall. Herodotus reported that Necho II, Pharaoh of Egypt, in about 600BC, sent his Phoenician sailors all round Africa, from the Red Sea to the Mediterranean. They navigated by following the coastline, and the journey took three years, mainly because they had stop in order to plant and harvest crops. Assuming that this famous story of Herodotus is true, these sailors must have seen coconuts growing on the East African coast. But we can be confident that they did not attempt to introduce coconuts into the Atlantic. There is no reason why they should have even contemplated doing so, and even if they had, they obviously failed. But, to the best of our knowledge, this was the one and only opportunity, prior to Vasco da Gama, for coconuts to have reached the Atlantic.

The civilizations of the Tigris-Euphrates and the Indus rivers probably developed boat transport similar to the Egyptian. There was also maritime trade between these two river systems, but it seems that these ocean-going boats also clung to the shore lines. Much later, the Arabs developed their ocean-going dhows, characterised by the lateen sail which allowed them to sail into the wind. They dominated the northern Indian Ocean, and they relied on the monsoon winds to take them to India, and back again, during the appropriate seasons.

Some short ocean journeys undoubtedly occurred across open ocean in ancient times, because the Canary Islands were colonized at a very early date by the now extinct Guanches who, however, had subsequently lost all knowledge of sailing. Plutarch, and Pliny the Elder, both wrote of these islands, their knowledge apparently derived from Phoenician sailors, who would have had to cross about one hundred miles of open ocean to reach them. Similarly, many of the Caribbean islands were colonized by comparable sea journeys, well before the arrival of the Europeans.

We know that the ancient Romans actually crossed the Atlantic, because the under-water remains of a Roman cargo have been found in the Bay of Guanabara, on the South American Coast, near Rio de Janeiro. It seems that this Roman journey was accidental, resulting from a storm. After all, Brazil had been discovered, and claimed by Portugal, in 1500, under very similar circumstances. The Portuguese explorer Pedro Alvares Cabral was trying to reach the Indian Ocean. He was becalmed when a storm blew up and carried him across the Atlantic to South America. Unlike Cabral, however, those unfortunate Roman sailors never made it back because, obviously, their ship was sunk. It seems that the Roman State apparently never did know about the New World. They knew only about ships that never returned.

Unfortunately, crass patriotism has interfered with this remarkable archaeological discovery. It seems that certain governments did not want Columbus and Cabral superseded as the discoverers of the New World. The Brazilian authorities covered the entire underwater site with dredger sediments, and declared it a restricted zone. So the actual remains of the Roman ship have never been found. But more than fifty Roman *amphorae*, of irrefutable provenance, have been recovered.

In the entire history of navigation, the ancient Austronesians were supreme in their navigational skills, and they put all other sailors to shame. They routinely, and deliberately, sailed directly *across* oceans, in boats that were so seaworthy that they

could survive mid-ocean storms. These sailors were out of sight of land for weeks, even months, at a time. Their navigational skills were phenomenal, indeed, incredible, because they had no compass, no sextant, no chronometer, no navigational charts, and, throughout most of their area, no Pole Star. And yet the total range of their travels took them considerably more than half way around the world. They even reached South America many centuries before either the Chinese or Europeans had built ocean-going ships.

The Austronesian family of languages apparently originated in Taiwan. The first of their navigators started sailing from Taiwan to Luzon and Borneo as early as 4000 BC, and they had begun to populate other islands to the South by 2000 BC. They reached Madagascar and Fiji during the second millennium BC. And they discovered Easter Island in 400 AD, Hawaii in 600 AD, and New Zealand in 750 AD.

Because of their sailing skills, the Austronesians were able to find and colonize the remaining, uninhabited land in the world. This land consisted of remote ocean islands, and they were uninhabited for the simple reason that they could not be reached by walking, or by short sea journeys. And they were available to the first people capable of ocean travel. The question that concerns us here is how the Austronesians solved the apparently insoluble problems of sailing across oceans. These problems, after all, were not solved by the Chinese until the fourteenth century AD, or by the Europeans until late in the fifteenth century AD.

The Austronesians navigated mainly by means of an exceptional knowledge of the stars. They had incredibly accurate *mental* maps of the night sky, and they knew the exact position of any star close to the horizon. They could thus sail towards any known star that happened to be low in the sky. They also made use of the rising and setting of the sun and moon, and they often relied on prevailing winds. And they

could detect land from many miles away by the character of the waves, the shape of the clouds, and the presence of sea birds.

The problem of scurvy was not satisfactorily solved by Europeans until Nelson turned British sailors into limeys by feeding them lime juice, late in the eighteenth century. And the problem of storing large quantities of fresh water had to wait for the industrial revolution, and the manufacture of steel tanks, before it was completely solved. Yet the Austronesian sailors did manage to store water fit to drink, and to store fresh supplies of Vitamin C, many millennia before the days of steel tanks and refrigeration.

The problem of storing water was crucial. Fresh water will not keep for more than a few days in an organic container, such as a bamboo, gourd, or calabash. Wine, because of its 12% alcohol, can be stored in organic containers such as wine skins and wooden barrels. But pure water tends to rot the container, and the water spoils. This decomposition is at its most rapid in the warmth of the tropics. Equally, the Austronesians had no glass or glazed pottery bottles, and unglazed pottery will not hold water for long. Indeed, in many parts of their eastern zone, they had no pottery at all, because there is no clay on small coral islands. In any event, pottery is fragile stuff, as anyone who has been at sea in a storm will know. Because these people had no metals, the only other possible container for water was sea-shells, but these presented insuperable problems of spillage and evaporation.

The problem of fresh fruit and vegetables was just as difficult. A lack of Vitamin C causes the symptoms known as scurvy, which include swollen and bleeding gums, loosening of the teeth, aching joints, sub-cutaneous bleeding, easy bruising, and slow healing. In the sixteenth and seventeenth centuries, scurvy frequently led to the death of European sailors, whenever the lack of Vitamin C was prolonged. This vitamin, which is needed daily, can be obtained only from fresh fruit

and vegetables, which do not keep for long without refrigeration. This produce must be fresh because Vitamin C is destroyed by cooking. Even if the Austronesians had had the means of bottling fruit, it would not have served their purpose. Equally obviously, the modern alternative of synthetic ascorbic acid was unavailable. The ancient Chinese used to solve this problem by carrying potted plants on some of their larger ships, but this was not practical on the Polynesian boats.

Sailors who lack fresh fruit and vegetables die after a few weeks. Without fresh water, they die after a few days. Clearly, the Austronesian sailors solved both of these problems with the coconut, which provides both drinking water and Vitamin C, in a living container that can be preserved unopened for months.

The center of origin of the coconut coincides quite closely with the center of origin of the Austronesian family of languages. Apart from its close relative, the rare double coconut (*Lodoicea maldivica*), which occurs only in some of the islands of the Seychelles, in the Indian Ocean, the coconut is the largest seed in the world, and it is the only seed that carries its own supply of fresh water.

This reserve of water permits germination on dry, sandy beaches where the seed is dispersed naturally by floating on sea water. There is enough potable water in the seed to allow the first leaf to grow and to start photosynthesizing, and to permit a root to grow down to the fresh water "lens" of the Ghyben-Herzberg effect. This effect is due to the fact that coral is porous, and fresh rain water floats on the heavier sea water inside the porous rock. This floating fresh water is roughly in the shape of a lens that is thick inland, and thin near the shore. But, even on the shore line, there is enough fresh water to support the growth of coconuts.

As we have seen, for ancient people, the incentives to domesticate the coconut were defined by the attributes of a modern drink-dispensing machine. Domestication eventually produced a dwarf palm with many, small coconuts that were close to the

ground, easier to reach, and easier to open. However, unlike the wild type coconuts, these domesticated coconuts would not survive floating on sea water, and their dispersal depended entirely on human agency. These seed-dispersing people were undoubtedly Austronesians.

It is likely that the Austronesians carried the small, domesticated coconuts on short sea journeys with the intention of using them as seed on islands that had only the wild type of coconut. But, on their long sea journeys, they probably took the large wild type nuts for consumption. These large nuts had the considerable advantage that, if necessary, they could be stored below the deck of their double canoe, in nets, floating in sea water.

The so-called "milk" of a coconut is so rich in organic nutrients that it is an ideal medium for plant tissue culture. The so-called "meat" of a coconut is also highly nutritious, and the combination of this food and drink contains enough Vitamin C to prevent the development of scurvy.

Like the spread of the Indo-European family of languages (Chapter 6), the spread of the Austronesian family of languages thus depended on a *plant*. But it did not depend on agriculture, and the wave of advance that occurred with the cultivation of wheat as a staple food. The Austronesian plant was crucial in quite a different way. The coconut enabled their sailors to cross oceans without dying of thirst, or dying of scurvy.

We must note also that the development of these navigational skills depended entirely on the environment. Had the coconut not existed, the long-distance sailing would never have occurred, and Austronesian family of languages would have a very limited distribution today. Had the centre of origin of the coconut been in the Caribbean, these navigational skills might have been developed by Amerindians. The genetic differences between Austronesians and Amerindians are trivial. But the

presence or absence of the coconut was crucial. The wheat farmers of Europe, and the rice growers of China, also lacked the coconut. With all their civilisation, their growth of cities, and their industrial and scientific abilities, it took them several *millennia* to catch up with the Austronesian navigational skills.

The coconut thus solved two of the problems of ocean sailing. The other two were navigation and storms. As we have seen, navigational problems were solved by sheer memory, passed down from generation to generation by people who had no writing, and no method of recording their knowledge. The problem of storms was solved by the superb design of their boats, which were essentially tropical in design, and which were entirely different from the Chinese or European ocean-going ships. No one can accuse these wonderful people of being either backward or unintelligent, just because they lacked a major staple, and they failed to develop cities.

Trade and Exploration

Once the Austronesian sailing skills were fully developed, they had two kinds of large boat. One was the war canoe, holding some eighty men. As this canoe was powered by human muscle, its range was severely limited. The other boat was the long-range double canoe, which was similar to a large catamaran. Although it too could be used as a warship, it was used mainly for exploration and trade. The last of these double canoes to be built by the traditional craftsmen was the *Ratu Finau*, in 1913. This was a relatively small boat which is now preserved in the Suva Museum, in Fiji.

The deck of these canoes was large enough to have a cabin, in the sense of a small house, and a bed of gravel for a cooking fire. The double canoe was powered by wind, having up to three masts and sails. It was also very sea-worthy and, apparently, the only factor that seriously limited the duration of its journey was the

size of its cargo of coconuts. Food, in the form of fish, was usually plentiful. These long-range vessels were used for both trade and exploration.

Austronesian maritime trade included the collecting of sea cucumbers in northern Australia, for sale in China, where they were highly prized as a culinary delicacy, and as an aphrodisiac. There was also a regular trade in cloves (*Eugenia caryophyllus*) from the Spice Islands to China (Chapter 10). Even more remarkable was the regular trade in cinnamon (*Cinnamomum zeylanicum*) from Indonesia, directly across the Indian Ocean, to Madagascar, even before the time of Christ. This trade is described later (Chapter 10), and the cinnamon was destined for the markets of ancient Rome. These ancient Indian Ocean navigators also took the banana (*Musa* cultivars), the Asian yam (*Dioscorea alata*), and rice (*Oryza sativa*), as propagating material, from Asia to Madagascar. The banana and Asian yam later became important food plants in much of Africa.

At that time, Madagascar was an uninhabited island. The modern inhabitants of Madagascar are descended from these early navigators, with some mixing of Arab and African genes, and their language belongs to the Austronesian family of languages. They also have an ancient tradition of growing rice in the Asian manner, in flooded paddies. Knowledge of this highly productive method of cultivating rice did not reach mainland Africa until quite recently.

The Hunger Compulsion

Austronesian exploration journeys were made with the primary objective of finding new, uninhabited islands for colonization. The incentive for these journeys was almost certainly pressure of population on the home island, possibly aggravated by a famine, after a typhoon had destroyed crops. It was the hunger compulsion (Chapter 1) that induced them to undertake those incredibly dangerous and risky

migrations, covering thousands of miles of open ocean in boats that were very small by modern standards.

Early European explorers have described some of the horrors of over-population on small Pacific islands. The principle method of birth control was infanticide, particularly of female children. This extreme measure was forced on them by shortages of food, and by the appalling social pressures, and internal hostilities, that develop with over-crowding. It is clear that the people who set out in what, for us, were very small boats, to find other islands, had little choice in the matter. They were probably being expelled, against their will, and their chances of survival were not good. It was only a fortunate few who found uninhabited islands, and who became founder populations. Tragically, in the course of time, their descendants would also reproduce beyond the carrying capacity of their limited island environment, and the tragedy of over-population, and hunger compulsion, would be repeated, again and again.

Sweet Potato

Austronesian exploration was so effective that, by the time of European ocean travel, there were few 'desert' (i.e., deserted, not waterless) islands left in either the Pacific or the Indian Oceans. Indeed, the very name Polynesian means 'many islands' and is indicative of the thoroughness of their exploration.

In the eastern extremity of their travels, at least one Polynesian exploration journey reached South America. These explorers brought back the sweet potato (*Ipomea batatas*) which, at that time, occurred only in the Americas. To this day, Polynesians refer to the sweet potato by its north Peruvian name of "kumara". They took kumara to all their islands, including Fiji, Hawaii, and New Zealand, well before the arrival of Europeans. This artificial distribution of sweet potatoes provides the

only really convincing evidence in support of Thor Heyerdahl's *Kon Tiki* hypothesis, which postulates that ancient people had contact between continental South America and the islands of the South Pacific. However, it would be a mistake to conclude that the people of the South Pacific islands originated in South America, because the natives of this continent have languages that are quite different from the Austronesian family of languages.

In the early sixteenth century, the Spanish took the sweet potato from the West Indies to Spain, and the Portuguese then took it to both West and East Africa, to India, and as far east as Indonesia and Papua New Guinea. In all these areas, it is known by its Caribbean name of ‘batata’, and the English word “potato” is a corruption of this Caribbean word which, in Spanish, became ‘patata’.

The Spanish took the sweet potato across the Pacific, from Acapulco, in Mexico, to the Philippines, where it is known by its Mexican name of “camote”.

The Austronesian family of languages thus has three entirely different names for this exotic food crop, based on three quite separate places of origin in the tropical New World, and several quite distinct journeys of exploration, undertaken by three quite different groups of people.

Founder Populations

The Austronesian double canoes could not carry many people. Obviously, the longer the journey, the fewer the people, because there was a limit to the number of coconuts that could be carried. It follows that any boatload of people arriving on a strange shore would be, at most, a small founder population.

If that distant shore was part of a large land mass which was already inhabited, such as Australia, Papua New Guinea, South America, or Africa, the founder population had three possible courses of action. They could stay only briefly, for

collecting or trading purposes, and then leave. They could stay and be exterminated by hostile indigenous people. Or they could stay as colonizers among friendly, but far more numerous, indigenous people. But in this last case their language and their genes would be completely swamped by superior numbers.

In any of these circumstances, their small boat populations could not spread their language into land that was already inhabited. In this sense, they were the very opposite of the wave of advance model, in which superior numbers moved into areas of low population density. The Austronesian boat people represented inferior numbers being swamped by moving into superior numbers. Consequently, the Austronesians could establish their language, and their genes, *only* in uninhabited islands, such as Madagascar or New Zealand, and the thousands of smaller islands in the Pacific and Indian Oceans. These islands, of course, were uninhabited because they could not be reached by migrant peoples who depended on walking, or by coastal navigation.

It is noteworthy that other small founder populations also failed to establish themselves on territory that was already inhabited. The Vikings, for example, failed to establish themselves in Vinland, and the first Spaniards left behind by Columbus, in Hispaniola, were exterminated by hostile Caribs. The English has a similar experience when Walter Raleigh left a colony of English people on Roanoke Island, off the Coast of Virginia, in 1587. These people simply disappeared. Europeans who arrived later in the New World established themselves partly because of superior weapons and armour, but mainly because their predecessors had inadvertently introduced epidemic diseases which decimated the indigenous people, killing up to ninety percent of them in some areas (Chapter 5).

Two Sub-Families of Austronesian Languages

It is also worth noting that the Austronesian family of languages is divided into the Western and the Eastern sub-families. The Western sub-family is spoken by some 200 million people, while the Eastern sub-family is spoken by only one million people. There appear to be two reasons for this disparity.

The Western sub-family is spoken by people who are living on large islands, such as the Philippines, Indonesia, and Madagascar. These people cultivate rice in flooded paddies. As we have seen, (Chapter 7) paddy rice has several times the yield of wheat in the North American prairies and, furthermore, two or even three crops a year are often possible, compared with only one wheat crop a year in North America. Paddy rice thus produces several times, and possibly up to fifteen times, as much cereal as North American wheat. And rice cultivators have been doing this for three or more millennia. Rice culture thus permitted very high population densities, and the large islands permitted very large total populations.

The Eastern sub-family, on the other hand, was spoken by people living originally on small coral islands, where rice paddies are not possible. This is because the bedrock is too porous, and the water supply is inadequate. The knowledge of rice cultivation, to say nothing of the rice germplasm itself, consequently died out among the people speaking the Eastern sub-family of languages. Their population densities remained relatively low, and their small islands limited their total population. When these people did manage to colonise large islands at a later date, such as Fiji, Hawaii, and New Zealand, they had already lost both the knowledge and the germplasm of this crop.

World distribution of coconuts

We have seen that the centre of origin of sweet potatoes was in tropical America, and the centre of origin of coconuts was in tropical Southeast Asia. The two centres were thus half a world apart. We have seen also that the sweet potatoes were taken by Austronesians to New Zealand and Hawaii, by the Spanish to the Philippines, travelling across the Pacific Ocean. And the Portuguese took them to Africa, and the Indian Ocean, by travelling across the Atlantic. Interestingly, the dispersal of coconuts was in exactly the opposite direction.

The natural dispersal of the large, wild type of coconut, by floating on sea water, extended to India, the east coast of Africa, and many of the tropical islands of the eastern Indian Ocean and the western Pacific Ocean. However, these coconuts could not reach the Atlantic. Nor could they cross the eastern Pacific in a viable condition, and they could not colonise the west coast of the Americas. But the Spanish explorer Oviedo claimed that coconuts occurred on the west coasts of tropical America when the Spanish first arrived and, it seems, they can only have been taken there by Polynesians. It seems also that the dwarf, domesticated coconut never reached India, Sri Lanka, Africa, or the New World in ancient times. The reason for this is obscure, but it may be associated with unfavourable survivial conditions in Austronesian boats.

This distribution of coconuts was thus a stable situation which represented the limits of both natural and artificial dispersal. It seems also that this stability had endured, with only minor changes, for several thousand years.

There is no evidence whatever for coconuts on any of the shores of the Atlantic before the Portuguese introduced them in the early sixteenth century. When Vasco da Gama arrived in the Indian Ocean, in 1498, he found coconuts growing on both the African and the Indian tropical shores of that ocean. This

was the first time that Europeans had ever seen this plant and the Portuguese quickly appreciated its value as a means of carrying drinking water on long sea journeys. The Portuguese soon planted coconuts on the tropical African shores of the Atlantic and, later, the Caribbean and the Atlantic shores of tropical America.

Soon after this, the Spanish established their galleon trade between Acapulco, in Mexico, and the Philippines. They took coconuts from the western Pacific to Mexico and, eventually, all the Pacific shores of tropical America. But these were a different kind of coconut from those in the Atlantic. The Portuguese had moved the wild type of coconut, taken from East Africa, across the Atlantic. The Spanish had moved a hybrid type, that was part wild and part domesticated, across the Pacific. The two types came to within a few miles of each other on the opposite shores of Panama but, it seems, having both travelled halfway around the world, they never came into breeding contact until quite recently. The Atlantic wild type became known as the "Jamaica Tall", and the Pacific hybrid type was called the "Panama Tall".

The *natural* distribution of the coconut was remarkably close to the distribution of the Austronesian family of languages, and both distributions extended half way around the world. In fact, the spread of a plant species, and the spread of a family of languages, have many similarities. Both the Austronesian family of languages, and the coconut, owed their dispersal to the fact that they could float. Differences from the original parent increase with distance from the centre of origin. Obviously, the greatest differences will occur with the greatest distances. Thus the greatest language differences within the Austronesian family are those between the extreme west, in Madagascar, and the extreme east, in the eastern Polynesian islands. Much the same is true of coconuts.

Coconut Diseases

In general, coconuts are remarkably free of pests and diseases. When pests and diseases are important, it is usually because of a world re-distribution of these parasites by people.

An intriguing hypothesis was developed by Luigi Chiarappa, of the Food and Agriculture Organization of the United Nations. If a coconut is floating for many weeks in sea water, none of its parasites is likely to survive. The coconuts that occasionally reached the East African shore, long before the days of navigation, thus had two characteristics. They were pure wild type, because any reduction in husk thickness by domestication would prohibit their survival for such a long period in sea water. And they were free from parasites.

This natural dispersal created what may prove to be one of the oldest crop vulnerabilities (Chapter 5) in the world. After many centuries, indeed, millennia, of natural growth in the absence of parasites, the East African coconuts are likely to be very susceptible to those parasites, which occur in the area of origin, but which are absent from Africa and the Caribbean. These parasites, which may be insects, fungi, bacteria, or viruses, are likely to be obscure because, in the area of origin, the local coconuts have high levels of resistance to them, and the damage caused by the parasites is almost undetectable.

The Pacific coconuts have remained in closer breeding contact with their centre of origin. This is partly because of a virtually continuous natural distribution, at least as far as the central Pacific, and partly because of the frequent movement of nuts by people. For this reason, the Pacific coconuts are more likely to be resistant to the obscure parasites in the centre of origin.

One of these parasites, a phytoplasma, causes a disease known as “lethal yellowing” which came close to destroying the coconut industry of Jamaica, and has

totally destroyed the ornamental coconut palms of Florida, which were once such a beautiful tourist attraction. This disease is now destroying the coconut industry of the Yucatan Peninsular in Mexico, and other areas of the Caribbean.

The Jamaican coconut industry was saved by crossing “Panama tall” with “Malaysian dwarf” to produce high yielding, hybrid palms. The dwarf parent is the domesticated type, and it comes from the centre of origin. It is highly resistant to lethal yellowing. Because it comes from the Pacific coast of Central America, the “Panama Tall” is also resistant to lethal yellowing. The hybrids between these two types are high yielding and vigourous. And they are resistant to lethal yellowing.

This was apparently a re-encounter disease (Chapter 5). The wild type coconut in East Africa was separated from its parasites in antiquity and was eventually taken half way around the world to Jamaica. Then, by some accident which is not understood, the disease was also taken to Jamaica, some four centuries later. The result was lethal yellowing disease, which was new to science, but not new to nature. This explanation may also apply to other obscure diseases of coconut, such as Kerala wilt in India, and a similar wilt disease in West Africa. But, with the Chiarappa hypothesis we at least know where to look for resistant stocks.

Human Diseases

The Austronesian explorers, at sea for weeks in their small boats, were very similar to floating coconuts, from an epidemiological point of view. Anyone who was sick was unlikely to survive the rigours of such a journey. It follows that all the Austronesian founder populations tended to be free of infectious diseases. The further they travelled from mainland Asia, the more diseases they left behind, and the greater their vulnerability to re-encounter diseases. Their small island populations were thus very susceptible to these re-encounter diseases when human contact was established

by European sailors. Sadly, it was the Polynesians who had travelled the farthest, and who were the most vulnerable. They were devastated by re-encounter diseases, just as the people of the New World and Australia were devastated. This was true of New Zealand, of Hawaii, and all the smaller Pacific islands.

The Copra Trade

The coconut has had yet another dramatic influence on history. In the nineteenth century, it was discovered that vegetable oils were an excellent substitute for the animal fats used in the manufacture of soap. Originally, the animal fats came entirely from farm animals. Later, the supply was supplemented, and then dominated, by whale oil. However, as the demand continued to increase, the whale populations declined dramatically, and the supply of animal fats became hopelessly inadequate for the demand. The discovery that vegetable oil could be used as an alternative solved this problem, and led to huge reductions in the price of soap, and huge increases in its use. For the first time in history, entire populations of people could be clean.

This industrial discovery also led to large increases in the demand for vegetable oil and, in those days, the most prolific oil producing plant was the coconut. And, oddly enough, the most useful coconut for these industrial purposes was not the domesticated type, but the wild type with its large nuts. Coconut plantations began to be established throughout the tropics, mostly near the sea for ease of transport and export, and because it was believed that the seashore was the best environment, being the natural habitat of coconuts.

Coconuts became known as the “lazy man’s crop” because, once the plantation was established, it was productive for more than half a century, and the owner had nothing else to do except sit back and wait for the ripe nuts to fall to the ground. In

many tropical islands, a tradition developed of planting a coconut farm for each son. When the young man married, a plantation would be given to him on the occasion of his wedding. He and his wife were then set up for life.

The ripe nuts are cut open and the "meat" is dried in the sun to become *copra*. Each nut produces about a third of a pound of copra. High quality copra contains 5% moisture and up to 70% vegetable oil. After the oil is extracted, the residue or "cake" is used as cattle feed. The rapidly increasing demand for vegetable oils led to an entirely new phenomenon called the copra trade.

There are many thousands of small islands throughout the tropics which are not on any normal shipping route. The copra trade meant that the people of these islands had a new and profitable cash crop. Previously isolated islands began to receive regular visits from small ships whose captains were collecting copra, in exchange for either money or trade goods. Suddenly, these thousands of islands were no longer isolated. Most copra boats carried a few passengers, and the people most eager to reach these obscure islands were missionaries. And most missionaries set up churches, schools, and hospitals and, in their own way, brought these isolated, tropical people into the nineteenth and twentieth centuries. Most of these isolated people were, of course, Austronesians.

So, for the second time in history, the coconut was responsible for a massive spread of culture. This time, it was not the Austronesian genes and languages that were being carried halfway around the world by brilliant sailors who possessed fresh coconuts to drink. It was the self-styled benefits of Christianity, and modern medicine and education, that were taken to thousands of small tropical islands by foreigners who needed coconuts to make soap and margarine. Because of the coconut, the inhabitants of these islands have had imposed upon them both the advantages and the disadvantages of modern civilization. One of those disadvantages was World War II

which did savage damage to many of their beautiful islands. The influence of the coconut on the Austronesian peoples has consequently been profound, in two entirely different ways, and in two quite separate periods of history.

Soap and Glycerin

Soap is manufactured by cooking vegetable oil (or animal fat) with sodium hydroxide, otherwise known as caustic soda. Two products emerge from this process, and these are soap and glycerin. In 1846, the Italian chemist Ascanio Sobrero mixed glycerin with nitric acid, and he produced nitroglycerin which, to this day, remains one of the most powerful chemical explosives known. When nitroglycerin explodes, it produces gasses with a volume 1200 times greater than the original volume of the explosive. If this happens in a confined space, such as an artillery shell, the effect is quite literally shattering.

Nitroglycerin is a “high” explosive. That is, when exploding, the flame of combustion travels through the explosive faster than the pressure wave of the explosion. This is called detonation. In contrast, with a “low” or “slow” explosive, such as old fashioned gunpowder, the flame travels behind the pressure wave, and the explosion is relatively mild. Low explosives are used as propellants for shooting shells or bullets out of guns. But, if a high explosive were used as a propellant, it would blow the gun to pieces.

Liquid nitroglycerin is very unstable, and it is liable to detonate spontaneously, if it is not kept refrigerated. It is thus very dangerous, and schoolboys playing with their chemistry sets are advised to leave it strictly alone. In the 1860s, Alfred Nobel, of Nobel prize fame, developed “dynamite” in which liquid nitroglycerin was mixed with an absorbent, inert substance, such as powdered charcoal, or diatomaceous earth, to produce a solid explosive that was safe. He also invented blasting gelatin, and

ballistite, which is a smokeless powder for rifle cartridges. This was an important military advance over the old black powder that used to produce a cloud of white smoke which gave away a rifleman's position. Later developments led to the various chemical explosives of modern shells and bombs.

However, to do Alfred Nobel justice, it must be added that he became a multi-millionaire mainly from developing the Russian oil fields at Baku, at the same time that John D. Rockefeller was making his money out of American oil. The Nobel prizes are not quite as tainted as some people believe. And they were established in 1901, long before World War I gave explosives, and the war profiteering that resulted from them, a nasty reputation.

It is a sad reflection of our times that the demand for glycerin, in the manufacture of explosives and armaments, often exceeded the demand for soap, and our need to keep clean. But the double demand for both soap and explosives meant that the world demand for coconuts increased enormously, and copra became one of the more important international commodities.

Nowadays, the supply of coconut oil has been heavily augmented with other vegetable oils from crops such as oil palm, maize, soy bean, cotton, and canola. Nevertheless, the world demand for soap is now so great that even the total supply of vegetable oils could not meet it. A shortage of soap is not usually thought of as a limit to the carrying capacity of the environment. But, were it not for the development of synthetic soapless detergents, there would be an acute, world shortage of vegetable oils, and the soap that is made from them.

It should be added, perhaps, that the soapless detergents are superior to true soap in various ways. In particular, they are unaffected by hard water, and they function better than soap in cold water. They are also much easier to manufacture.

Chapter Ten

Spices

In terms of their historical importance, the first European voyages of discovery, in the late fifteenth century, were far more significant than modern day space travel. They certainly had a greater impact on human beings, all over the world.

And, in terms of human courage, they involved many more people, travelling into an equally uncertain danger, for periods that lasted months, even years, rather than the short periods that space travellers have achieved so far. In terms of scientific discovery, also, the fifteenth century explorations were at least as important as modern space travel although, obviously, we still do not know what further space exploration may reveal.

These European explorations discovered the New World. They also proved that the world was round, and they revealed two entirely new routes to the Far East. Of far greater importance, however, they took Old World crops to the New World, and they brought New World crops to the Old. The consequences, in terms of the carrying capacity of out total environment, were immense.

The Portuguese discovered the route round Africa, to the Indian Ocean, India, Ceylon, the Spice Islands, and China. And they were mainly responsible for taking New World crops to the Old World. Of these, the most important were maize, potatoes, haricot beans, sweet potatoes, and cassava. The Spanish, of course, discovered the New World by crossing the Atlantic. Soon after this, they discovered the route round Cape Horn into the Pacific Ocean and, in the words of a famous schoolboy howler, they "circumcised the world with a sixty foot cutter". They were

responsible for introducing most of the Old World crops, such as wheat and cattle, to the New World.

These journeys became possible because the Portuguese had designed an entirely new kind of sailing vessel called a caravel. This was a relatively small craft, compared with the large warships and heavy cargo galleons of the time, and it was intended specifically for exploration. It was very seaworthy and it had a good ability to sail into the wind. At the time, the Portuguese were probing further and further down the west coast of Africa, hoping to find an alternative route to India.

The Spanish were quick to copy these Portuguese ships, and Columbus crossed the Atlantic in three caravels. The Dutch and the English also copied and improved them and, suddenly, exploration was all the rage. The caravel was the fifteenth century equivalent of our space capsule. But these new geographic discoveries must have been considerably more exciting to people of that time than our own space explorations are to us.

The principle motive that prompted European exploration was an ancient monopoly of goods from the fabulous Orient. This monopoly was valuable beyond belief, and it accounted for the incredible wealth of both Venice, and the Ottoman Empire in the Middle East. It included all the spices, as well as tea and silk from China. The Portuguese and the Spanish were determined to break this monopoly. With their new caravels, the Portuguese sailed east, and the Spanish sailed west.

At this distance in time, it is difficult to believe that all this expense and exploration, and these incredible feats of courage, were all inspired by such an insignificant article of trade as *pepper* with a few other spices, such as cloves, nutmeg, cinnamon, and ginger, as well as tea and cloth made of silk. And that, in some cases, it was centuries before the value of the recently discovered, New World crops, such as potatoes (Chapter 11) and rubber (Chapter 12), was fully appreciated.

In the end, of course, these monopolies became meaningless. This was mainly because competitors starting growing spices in other parts of the tropics. And New World red peppers became a superior, and much cheaper, alternative to black pepper. The spices were still valuable, of course, but they were no longer a source of monopolisitic wealth. And people outside of China learnt how to cultivate the silk worm, although Chinese silks are still the finest in the world.

The Portuguese Explorations

The Portuguese prince, and younger brother of the King, who was known as Henry the Navigator, sent explorers further and further down the west coast of Africa. He was trying to find an alternative route to the Far East and, when he died, his nephew, King John II, continued the exploration.

In 1488, the Portuguese explorer Bartholomeu Dias was caught in a storm and, quite unwillingly, he was blown into the Indian Ocean. He became the first to sail past the Cape of Good Hope, and to prove that the Indian Ocean could be reached by sailing round Africa. He did this when Christopher Columbus was still petitioning the King of Spain to be allowed to sail westward to India, and Dias' triumph did little to help Columbus. Dias visited the Cape of Good Hope again in 1500, when he sailed with Pedro Cabral, the discoverer of Brazil. This time, however, his ship was lost in a storm, along with three others, and everyone aboard all four ships was drowned, including Dias.

Between the two visits of Dias, Vasco da Gama rounded the Cape of Good Hope in 1498. He encountered hostile Arabs along the east coast of Africa, in Mozambique, Mombasa, and Malindi. Nevertheless, he built white stone pillars as future navigational aids, and these survive to this day. He then found a pilot who helped him to sail across the Indian Ocean to Calicut, on the Malabar Coast of India.

Here he found that the spice trade was firmly in the hands of Indian merchants, and Arab travellers who had complete control of the trade routes, by both land and sea, from India to the Mediterranean. The Venetians and, to a lesser extent, the Genoese, had established their own naval control of that sea, and their own spice monopolies.

Vasco da Gama also discovered that the Indian spice merchants were fabulously wealthy, and that none of his cheap trade goods were of the slightest interest to them. Nevertheless, Da Gama returned to Portugal to a triumphal welcome. As a navigational achievement, his success far exceeded that of Columbus, six years earlier, in 1492. Apart from anything else, da Gama had reached India, while Columbus only thought he had. Da Gama had found real Indians, and real pepper, while Columbus had found only false Indians, and false pepper. In the end, of course, Columbus' discovery was to prove far more important because it opened up the whole of the New World. But this cannot disguise his total failure when his discoveries are compared with those of da Gama, and when the comparison is made in terms of his stated objectives, assessed in the values of his own time.

Disputes between Spain and Portugal concerning rights of empire were first arbitrated by Pope Alexander VI in 1494. This arbitration was unsatisfactory and a modified treaty was later re-negotiated in the Spanish town of Tordesillas. The Treaty of Tordesillas gave Spain all lands to the west of the meridian now defined as 49° west of Greenwich, and Portugal all lands to the east of it, excepting that neither power might occupy lands that were already in the possession of a Christian king. Pope Julius II sanctioned the revised treaty in 1506. This treaty gave one of the disputed areas, the coast of Brazil, to Portugal.

Pedro Álvares Cabral had been named admiral of a fleet of thirteen ships sailing to India, in 1500, and following the route of Vasco de Gama. This route went southwest, in order to avoid the becalmed waters of the Gulf of Guinea. However,

Cabral went too far west, because of a storm, and he serendipitously discovered Brazil, and claimed it for Portugal. He then sailed for India and, after many adventures and several disasters, finally returned to Portugal, in 1501, with only four of his ships, but they were loaded with precious spices.

The Portuguese were determined to gain the spice monopoly, not by trade and fair competition, but by conquest. It must be remembered that Christian-Muslim rivalries and hatreds ran deep. They had also endured for centuries, dating from before the days of the crusades. The Arabs, after all, had conquered Jerusalem, and they had once conquered Spain, and threatened the whole of Europe.

In his second voyage to the Malabar Coast, in 1502, da Gama took a naval task force and, with the use of relatively novel cannon, he smashed Muslim sea power, and conquered the Indian traders. Neither the Arabs nor the Indians recovered from this totally unexpected blow, and the Portuguese became masters of the Indian Ocean, and of the spice trade.

The Portuguese founded colonies on the Malabar Coast. They soon ruled the whole of the west coast of India, and they established their capital in Goa. They now dominated the spice trade, and the Arab and Venetian grip on trade with the Far East was broken. The enormous wealth of the Ottoman Empire, and of Venice, began to decline. Venice became a fabulous city in decay, and the people of the Middle East did not begin to recover from this setback until the discovery of oil, more than four centuries later.

The spice trade was worth a mint of money to the Portuguese and they spent a mint of money to maintain it. For example, they conquered the old Arab town of Mombasa, on the East African coast in modern Kenya, where there is a fine natural harbour. They built Fort Jesus during the period 1593-1595. This is one of the last,

and most technically advanced, medieval castles ever built, and it is now preserved as a museum.

The Portuguese garrison was later besieged in Fort Jesus by the Arabs. The garrison sent a ship back to Portugal, calling for assistance, but the relieving force arrived too late, by only a few days, and they found the castle in Arab hands, and their compatriots dead. It is said that, when the castle fell, one of the Portuguese volunteered to show the castle treasure to the Arab leaders. He took them down to the dungeons, where there was a powder magazine. He was carrying a flaming torch, and he blew everyone in the party, including himself, to smithereens. He was, perhaps, the first suicide bomber.

The Spanish Explorations

The Spanish were much more bold in trying to reach India, China, and Japan by sailing west, at a time when the concept of a round earth was far from being universally accepted. As every schoolboy knows, Columbus found what he believed to be India in 1492.

Columbus was wrong. He had not reached India, although he believed he had to his dying day. It is fashionable to glorify Columbus, and he has probably had more places and institutions named after him than anyone outside the Christian hagiography. But what a blunder. The man was incompetent. His error led to many secondary errors. In particular, Columbus did more to confuse European languages than any man who has ever lived. He referred to the people of the New World as Indians. He called the islands of the Caribbean the West Indies. Maize became Indian corn. Because he could not find black pepper, he called chillies red pepper, and he called allspice, which has a seed similar to black peppercorns, Jamaican pepper, or pimento. To this day, we speak of India rubber and, when people in the New World

want to talk of the real India, and real Indians, they must preface everything with the word “east”.

However, we must not allow this linguistic confusion to detract from the importance of Columbus, or from the importance of the New World crops that were soon taken all over the world. When Columbus sailed to the New World, there was only one kind of pepper. Columbus did not find it because it is an Old World crop. Not wanting to return to Spain empty-handed, he took back an alternative, hot spice, which, as we have seen, he confusingly called pepper, and he distinguished it from the real, or black, pepper by calling it red pepper. The many varieties of this crop included sweet, green, yellow, and other peppers which, collectively, became far more important than black pepper. This is why the Portuguese pepper monopoly was never as valuable as they had hoped, even if they did well with other spices. Red peppers are so easy to grow, so cheap, and so delicious, that black pepper lost its supremacy beyond recall.

Then, of course, there were all those other New World crops which transformed the Old World. Potatoes and haricot beans transformed northern Europe, while maize and haricot beans transformed southern Europe, and most of Africa, to say nothing of the Far East. Sweet potatoes and cassava transformed the lowland tropics of Africa and S.E. Asia, including all the islands of the western Pacific. There were major increases in the carrying capacity of these environments, and human populations began to increase in all of them.

Amerigo Vespucci, an Italian contemporary of Columbus, did not believe that Columbus had found India. His estimate of the diameter of the Earth was far more accurate than that of Columbus. He accordingly believed that Columbus had found a "new world" lying between Europe and India, and he explored the east coast of South America, looking for a passage to a further sea that would reach India. He did not

find this passage but he gave his name to the Americas. In 1507, the map maker Martin Waldseemuller was so impressed with Vespucci's percipience and courage that he suggested the newly discovered land should be named after Amerigo.

It was Ferdinand Magellan, a Portuguese in the service of the Spanish king, who succeeded where Vespucci had failed. In 1520, he found the passage round Cape Horn which now bears his name, and which became an important shipping route until the opening of the Panama canal. Magellan then sailed the Pacific from east to west. His ship eventually returned to Spain, via the Indian and Atlantic Oceans, and his crew became the first people to circumnavigate the world. Sadly, Magellan himself was killed in a battle on Mactan Island, in the Philippines, and he was denied this fame.

But the Spanish reached the spice islands too late. The Portuguese were already established there, and the Spanish had to content themselves with claiming the Philippines. Columbus had goofed, and he never lived to appreciate that South America was an even bigger obstacle than Africa, on a much longer, and more difficult, route to India.

Nonetheless, while Portugal was establishing itself in the Indian Ocean, and winning the entire spice monopoly, Spain was claiming the whole of the New World, except for the Portuguese claims in Brazil.

Black Pepper

Black pepper (*Piper nigrum*) is a native of the Malabar coast of Southwest India, and the ancient Kingdom of Keralaputra. Much of this area is now the modern State of Kerala, where the Portuguese established a colony in the sixteenth century. They were conquered by the Dutch in the seventeenth century. Later, the British

defeated the Dutch, and gained control of the whole of India, except for Portuguese Goa, and the Independent Kingdoms, until Indian independence in 1947.

Pepper was one of the earliest and most important items of trade between India and ancient Europe. The ancient Greeks and Romans had a very high regard for pepper and, historically, it is one of the oldest spices. Its importance can be appreciated from the many attempts to establish monopolies, and the compelling necessity to break those monopolies. Food in ancient Europe was usually rather bland, and relatively tasteless. These people still had no sugar, and no tea, coffee, or chocolate. The only flavourings that the Europeans could produce themselves were honey, onions, garlic, saffron, mustard, horseradish, and various herbs. Most spices are the products of tropical plants which cannot be grown in Europe.

The need for spices in Europe was accentuated by the problem of having no winter feed for their meat animals, such as sheep and cattle. This meant that many animals had to be slaughtered in the autumn even though the existing techniques of meat preservation, such as salting and smoking, were rudimentary.

Throughout the winter, much of the meat tasted either very salty or plain bad and, quite commonly, it could be eaten only if its foul taste was smothered with pungent spices. Until the discovery of the New World, and red pepper, the only spice that would do this effectively was black pepper, usually mixed with garlic. The demand for black pepper was consequently high. Pepper also has preservative properties of its own, and the many varieties of European sausage, all of which contain pepper and garlic, represent meat preservation traditions that go back to the Middle Ages.

The pepper plant is a vine which is cultivated by training it up wooden posts. It is a relatively expensive crop to establish but, once planted, it is usually good for twenty years of production. The crop is propagated vegetatively from cuttings which

require two or three years to come into bearing. Pepper has a special feature known as dimorphic branching. This means that only the terminal shoots will produce new plants from cuttings. Cuttings taken from lateral shoots will merely continue to grow as lateral shoots, and they cannot be used for propagation. Coffee (Chapter 14), cotton (Chapter 16), and cocoa (Chapter 15) also have this habit of dimorphic branching, making the use of cuttings difficult in these crops also.

The peppercorns themselves are single-seeded fruits carried in long inflorescences with about fifty fruits in each inflorescence, looking rather like a small bunch of tiny grapes. Black pepper consists of the fruit which is picked when the green berries begin to ripen and turn red. The inflorescences are dipped briefly in boiling water, and are then left to dry. They then turn black and become the familiar peppercorns of commerce.

A peppercorn consists of both the seed coat and the kernel. The kernel is the hot, or peppery, part. The seed coat contains complex, and delicious, aromatic oils which contribute much to the quality of the spice. However, these aromatic oils are highly volatile and are soon lost by evaporation after grinding. This is why black pepper should always be freshly ground on to food, straight from a pepper mill.

The best pepper mills are made in France, by a firm called Peugeot. At the turn of the twentieth century, this company decided to diversify, and they chose to start making those new-fangled gadgets called horseless carriages. Peugeot cars are now famous for their excellence, but the company still makes pepper mills as well.

White pepper consists of the peppercorn kernel only. It is hot in the sense of peppery hot, but it has none of the delicious aromatic oils which reside in the seed coat. Peppercorns destined for white pepper are prepared rather differently after picking. The berries are left to ferment in water and the softened seed coat is then removed to produce whole white peppers. White pepper can also be produced by

milling off the seed coats of black pepper. A foolish speculator in London once tried to corner the white pepper market, but he went bankrupt before he realised that the trade could always produce more white pepper, simply by milling black pepper.

Cornering the market in black pepper has been an ambition of colonial powers and merchants throughout much of recorded European, and even United States, history. The ancient Phoenicians had a coastal shipping trade with the Far East. The Romans took over these trade routes, both overland, and with ships sailing from Egypt, usually within sight of the coast, through the Red Sea and the Indian Ocean to India. Later, the Arabs were to use the same routes, for their trade with Venice and Genoa.

In Roman times, Pliny complained to the Emperor Nero about the drain of gold used to pay for all the luxuries of the East, of which pepper was a major item. Nearly every Roman recipe included pepper and, to this day, old Roman gold coins can be found in archaeological digs in the Far East. A similar gold drain from Europe to India occurred during the Venetian and Genoese monopolies. This gold was eventually replenished mainly by the Spanish looting of treasure from the civilisations of the New World.

Red Peppers

Archaeological records indicate that chilies (English chilli, Spanish chili) were eaten in the Vale of Mexico in 7000 BC, and that they were cultivated in that area as early as 5000 BC. This suggests that chillies were among the first plant species to be domesticated in the New World.

Supporting evidence comes from the fact that no truly wild chillies are known. It is probable that the wild progenitors of chillies were exploited to extinction by

early hunter-gatherers, and that only the more valuable, cultivated forms were preserved by early farmers.

Red peppers, or chillies, (*Capsicum frutescens*) belong to the botanical family *Solanaceaea* to which potatoes (Chapter 11), tobacco (Chapter 18), tomatoes, and eggplants also belong. The variation within red peppers is incredible. As a rough and ready rule, the smaller the fruit, the hotter it is. For this reason, the largest fruits are known as sweet peppers when ripe, and green peppers when immature. The smaller fruits are the hot ones and, when dried and milled, provide red pepper. These smaller fruits are called chillies, from the word *chile* in the Nahuatl language of the ancient Aztecs.

Sweet peppers are also called pimiento in Spanish, and paprika in Europe. (Here is more Columbian linguistic confusion. The term pimiento, which is Spanish for pepper, should not be confused with "pimento", which is an English corruption of the same word, and used as an alternative name for allspice, *Pimenta dioica*, discussed later in this chapter). Paprikas are used extensively in salads and can be cooked in various ways. They are also used to make the red centres of stuffed olives. A special strain of paprika is grown in Hungary, and the dried fruits are ground into a powdered paprika that provides the characteristic flavour of Hungarian goulash.

The very small, very hot chillies are used in the preparation of Cayenne pepper. They are also used to make Tabasco sauce, which is manufactured in Texas, but named after one of the lowland, tropical states in Mexico. P.G. Wodehouse’s favourite character, Bertie Wooster, often used the slang phrase “pure tabasco”, which means “hot stuff”. Chillies are also the hot ingredient in most Indian curries.

Thackeray, in his novel *Vanity Fair*, relates how the fat Joseph Sedley, the Collector of Boggley Wollah, home on leave, played a mean joke at dinner on the young and innocent Becky Sharp, who was finding the Indian curry rather too hot. At

his prompting, Becky, who knew the word chilly, but not chilli, ate some very hot red peppers, thinking they would cool her down. In fact, for anyone who finds a curry too hot, the best way to cool the mouth is to eat the plain yogurt that true Indians traditionally serve with curries. Alternatively, either banana or milk is soothing, either during, or after, an over-peppered meal.

Chillies have often been used for much worse things than practical jokes. The ancient Aztecs used them as a punishment and also as a torture. An unmarried girl who looked at a man would have hot chillies rubbed into her eyes and, if she slept with him, she had hot chillies rubbed into her sexual parts. A torture that has been used for centuries, in many tropical countries, is to hang the victim upside down over a fire of burning, pungent chillies.

The sad thing about Columbus' disappointment over black pepper is that he never realized that his red peppers were vastly more important. Within a century of the discovery of the New World, chillies had become the most widely used spice of them all. India now produces nearly a million tons each year, and China produces even more.

In India, which is the home of black pepper, red peppers have largely replaced black pepper in curries. They are now used so comprehensively, and in such variety, that most Indians are reluctant to believe that this crop is new to their culture, and that it was introduced relatively recently by the Portuguese. There is a similar disbelief in China.

One of the reasons for the predominance of red peppers over black pepper is that red peppers have flavours that are much more than merely hot. And there is an enormous variety of these secondary flavours. When added to food in small quantities, red peppers can transform the taste of a dish, without necessarily making it hot or pungent. Many of the world's finest cuisines, such as the Mexican, Vietnamese,

Indian, Chinese, and Indonesian, depend very heavily on red peppers for much of their excellence.

Horseradish

The roots of *Armoracia rusticana* are grated, and mixed with oil, vinegar, and salt to produce the hot condiment known as horseradish sauce. This crop is propagated vegetatively mainly because true seeds are very rare, and there are many different clones which vary greatly in their hotness. The hottest of them rival red peppers, and they can be devastating if eaten incautiously. It seems that most of these clones are ancient and came originally from eastern Europe and Turkey. The plant is mentioned by Dioscorides in his classic herbal *De Materia Medica*.

It is thought that horseradish has a hybrid origin, and that this is why almost all its seeds are sterile. Even if a fertile seed does occur, it does not breed true to type, and it will produce a plant of dubious agricultural value. The various clones of horseradish may thus be several thousand years old.

Horseradish was one of the very few spices that were locally available to Europeans when the tropical spices were so prohibitively expensive. Although it cannot compare with either black or red peppers, horseradish is not to be despised and, to this day, it is still in demand, particularly as a condiment for use with roast beef.

Mustard

Mustard is prepared from the seeds of various species of *Brassica* which are close relatives of cabbage, cauliflower, Brussels sprouts, turnips, kohlrabi, broccoli, and kale. Other crops in the same botanical family, the *Cruciferae*, are horseradish, watercress, the true radish, rapeseed or canola oil, and nasturtium.

Brassica hirta is known as white, or yellow, mustard, and *Brassica nigra* is black, or brown mustard. Both these species originated in the Mediterranean region and have been cultivated for more than two millennia. These are the mustards mentioned in ancient Greek, Roman and Biblical records. A third species, *Brassica juncea*, is known as Indian mustard, although it probably originated in north eastern Africa and was taken to India and China in antiquity. *Brassica alba*, sometimes called *Sinapis alba*, is also known as white mustard, and is the mustard of "mustard and cress", the peppery young seedlings, which are eaten as a salad, like alfalfa seedlings.

In medieval Europe, mustard was even more important than horseradish as a means of disguising the taste of bad meat, and as a substitute for the vastly superior, and vastly more expensive, black pepper. Mustard was also used medicinally, and it was prescribed by physicians as early as Hippocrates in the fifth century BC. It was used internally, to stimulate salivary secretions, and the peristaltic action of the stomach. But its external use, as a hot poultice for relieving rheumatism and bronchitis, was more frequent.

The word mustard is a combination of 'must' and the Latin word *ardere*, to burn. 'Must' is newly fermented grape juice, and 'mustard' was simply 'hot must', produced when the 'must' and the ground mustard seeds were mixed as a condiment. Table mustard is prepared by grinding the seeds and mixing them with various combinations of salt, vinegar, wine, and spices of various kinds. As any the three different species of mustard can be used, or any one of a huge variety of blends of them, and as the choice of blends with other spices is infinite, the variety of table mustards is limitless.

Famous mustard production centres are Dijon and Bordeaux, in France, and Düsseldorf, in Germany. A famous English mustard is made by the firm of Coleman,

and it has long been believed that Colemans made their profits out of the mustard that was thrown away on the side of the plate.

In addition to being a table condiment, mustard is widely used in cooking, mainly in the preparation of sauces and, particularly, as a flavouring in various cheese and cream sauces. French cooking, more than most, is dependent on sauces, and the French probably make a richer use of mustard than anyone else. However, mustard is also a major constituent in Indian cooking and, of course, in North America, it is considered an essential flavouring for both hot dogs and hamburgers.

In the last few decades, Canada has become the world's largest producer and exporter of mustard. It is grown mainly in Alberta, and it is harvested with giant combine harvesters and transporters, and then taken to grain elevators, just like wheat (Chapter 6). The neighbouring States of Montana and the two Dakotas produce sufficient mustard to make the United States the world’s second largest producer. In general, the traditional mustard growing areas, with their small fields and scales of production, can no longer compete. But the traditional centres still make their famous mustards, frequently using seed grown in North America.

Ginger, Turmeric and Cardamoms

Ginger (*Zingiber officinale*), is the last of the ‘hot’ spices that is worthy of mention in an account such as this, and it is only mildly hot. It belongs to the botanical family *Zingiberaceae* and is a close relative of turmeric, the main spice of Indian curries, and cardamoms. All three plants look very similar but, whereas ginger and turmeric are obtained from the underground stems, the cardamoms are seeds.

Ginger is the most widely used spice in Chinese cuisine, and it is commonly added to Indian curries. It is frequently prepared by frying a mixture of green ginger

and freshly chopped onions until golden brown. This mixture can be added to almost any savory dish to impart a wonderful richness and flavour.

In the West, ginger was one of the earliest known of the oriental spices. Just as black pepper was used to disguise the taste of bad meat in medieval Europe, so ginger was used to disguise the taste of rancid, wholemeal flour. Hence the term gingerbread. Ginger was known to the ancient Greeks who corrupted its Sanskrit name *singabera* into the Greek *zingiberis*. Later, the Romans adopted this as the Latin *zingiber*, which was the name given to the genus by Linnaeus.

It is thought that the ginger plant came from India, which is possibly the botanical centre of origin. However, no wild plants of ginger are known and this suggests a very ancient domestication. Furthermore, ginger no longer sets seed, and it can be cultivated only as clones, which are reproduced asexually by vegetative propagation. This also suggests a very ancient domestication (see Chapter 17), particularly as numerous clones exist in the area of origin.

Ginger is mentioned in the *De Materia Medica* of Dioscorides, and it was also mentioned by Pliny. Until the Portuguese entered the Indian Ocean, the ginger that reached Europe arrived via the Roman or Arab spice traders already mentioned in connection with black pepper. The Arabs took ginger to East Africa not later than the thirteenth century.

The underground stems, or rhizomes, which are both the ginger of commerce and the propagating material, are easily transported in a viable condition. Ginger is thus one of the easiest of plants to be redistributed on a worldwide basis. The Portuguese took ginger from East Africa to West Africa in the sixteenth century and were soon able to produce their own supplies close to home.

Francisco de Mendoça introduced ginger to Mexico soon after Cortés had conquered the Aztecs. However, the main Spanish source of ginger was Jamaica

which is reputed to have produced 1000 tons of rhizomes for export as early as 1547. Jamaica exports ginger to this day, and many people regard Jamaican ginger as the finest in the world. It has an excellent aroma and a very light colour. African ginger usually has a less excellent aroma, and it is darker in colour, but very pungent. Indian ginger is very variable, depending on the area of production, but it is usually strongly aromatic. China is the largest producer of ginger and, like India, has a wide variety of types and qualities.

In modern use in the West, ginger is popular mainly in the production of gingerbread, biscuits, cakes, and pickles. It is also used in ginger beer and ginger wine. Preserved ginger is a confection which is usually imported from China, and is made by boiling ginger in a sugar syrup. Crystallized ginger is produced in the same way but it is dried and then dusted with sugar. It is excellent when covered with dark, bitter chocolate. Ginger can also be dried and milled to a powder. But, like black pepper, it is liable to spoil after milling. It is said that one can judge a cook by glancing at the stock of herbs and spices. Any good cook will have a bottle of powdered ginger in the kitchen. But the best cooks use only green ginger.

Like ginger, turmeric consists of an underground stem. It is famous for its bright yellow colour, and its use in Indian curries. Turmeric is not a hot spice but it is pungent and has a characteristic flavour which is the basis of most curries. The so-called curry powders of commerce are mixtures of spices, and a large variety are available with widely differing degrees of hotness. Ignorant cooks sometimes ruin a curry by trying to make it hot with excessive amounts of a mild curry powder. The best cooks, of course, mix their own curry powders.

Cardamoms are utilized as the dried fruits, and they are a minor spice used in flavouring curries, cakes, confectionery, and, in Arab countries, coffee. Cardamoms have medicinal value and are used as a masticatory. They are often added to Indian

betel nut quids for this reason. The main producers are India, Sri Lanka and Guatemala.

Cloves

Cloves can be highly pungent, but they are not hot. So, in this account, they form the boundary between the hot spices and the sweet spices. Pungency means that a spice has volatile components that are detected by the sense of smell, usually quite sharply. Hotness, on the other hand, is not detected by smell. It is detected by actual contact with the skin, usually the lips and tongue, and it causes a burning sensation. Cloves are so pungent that islands which grow them, such as the Moluccas in Indonesia, or Zanzibar and Pemba in East Africa, can often be smelled by sailors at sea, long before the islands come into sight.

Cloves are native to the Spice Islands, a group of small volcanic islands in the Molucca Sea (not to be confused with the port of Molucca, near Singapore), now part of Indonesia, located south of the Philippines, and west of New Guinea. The principle Spice Islands are Ternate, Amboina, Tidore, Mutir, Makyan, and Bachian.

The Portuguese were the first Europeans to discover the Spice Islands, in 1512, and they then cornered the market in cloves and nutmeg which, at that time, grew in these islands and nowhere else in the world. The Spanish were intensely envious of this trade and they attempted to reach the same area by sailing in the opposite direction, across the Pacific Ocean. As we have seen, they employed the renegade Portuguese navigator, Ferdinand Magellan, to lead their expedition, and, because he was so successful, the Portuguese never really forgave him.

With incredible hardships, and even more incredible courage, Magellan rounded Cape Horn and crossed the Pacific. Spain claimed the Philippines and used Manila as its staging post for its galleon trade across the Pacific, taking gold and

silver to China, and silk to Europe, with a relatively short land journey across Mexico, from Acapulco on the Pacific, to Vera Cruz on the Atlantic. But the Spanish never did gain access to cloves and nutmeg, principally because the Spice Islands were already in the possession of the Portuguese and, rivals though they were, the Spanish and Portuguese were too close to go to war on an issue such as this.

Cloves (*Eugenia caryophyllus*), are botanically interesting because they belong to the myrtle family *Myrtaceae*. This family includes the genus *Eucalyptus*, the famous gum-trees of Australia. Eucalypts have been taken to every tropical and subtropical area of the world where they are often the predominant trees. This gives most of these areas a characteristic and uniform appearance, quite different from their original looks, before humankind interfered so drastically in the world distribution of plants.

Originally, these gum-trees were confined to the Australian island continent. The myrtle family obviously evolved before continental drift separated Australia from South America, Africa, and Antarctica, but the gum-tree members of the family evolved after this separation, and were confined to Australia and some of its neighbouring islands. Cloves also evolved after the separation, but they evolved in Indonesia, and they survived only in the Spice Islands. The climatic range of clove trees is very limited and, even when cultivated, they thrive only in good soils, near the sea, and within ten degrees of the equator. This made them a very scarce and valued spice in antiquity.

The clove of commerce is an unopened flower bud which should be picked when it is just turning pink. The picked cloves are dried and they turn a dark brown to black. Picking cloves is a labour-intensive and difficult task. The buds must be picked at exactly the right time. The trees are large and the buds occur at the end of the branches. The trees are often infested with biting ants known in East Africa as *maji*

moto which is Swahili for “hot water”, and is descriptive of their painful bite. Pickers in Zanzibar are sometimes tempted to tear whole branches off the tree, and then pick the cloves in comfort and safety on the ground. Unfortunately, this procedure wounds the trees, which are then liable to succumb to a disease called “Sudden Death”.

The dried clove looks similar to a small nail and, indeed, the word clove is derived from the Latin word, *clavus*, for nail. This association of ideas occurs in several languages. In German, cloves are *Nägelchen* or *Nelkin*, meaning “little nails”. The French *clou*, the Persian *Nekhak*, and the Chinese *Ting-hiang* all have this connotation also.

China was the first large market for cloves and one of the uses made of them was to control halitosis, or bad breath. The Emperors of the Han dynasty, in the third century BC, required anyone who spoke to them to have a clove in his mouth for this reason. As we have seen (Chapter 10), these cloves were taken to China by ancient Austronesians sailing the oceans.

The ancient Chinese and Persians regarded cloves primarily as a medicine, and an aphrodisiac. The medical properties were mainly as a carminative, which is a drug used for reducing flatulence. Clove oil is also well known to be a mild anesthetic, and it is useful against toothache. It is also reputed to have antiseptic properties. The best clove oil is distilled from the cloves themselves, but inferior oils can be obtained from the leaves and young bark. The dried fruit are known as ‘mother of cloves’ and have an inferior aroma. They are often used as an adulterant. Clove oil is one of the many so-called ‘essential’ oils, meaning ‘essence’ rather than indispensable.

Cloves were known in the Mediterranean area during the later stages of the Roman Empire, as well as in medieval Europe, and they were extremely expensive. After the Portuguese had discovered and colonized the Moluccas, and established a

valuable monopoly in this spice, the Dutch established a colony at Batavia, the modern Jakarta, and entered into competition with the Portuguese.

Cloves then became the subject of one of the more scandalous monopolies in the early seventeenth century. The Dutch had wrested control of the Spice Islands from the Portuguese in 1605, and this had given them complete control of the clove and nutmeg trades. However, under Dutch control, both clove and nutmeg production reached a state of glut, with large supplies stored at Batavia (modern Jakarta), and other stocks in Amsterdam.

To understand the iniquity of the subsequent action by the Dutch United East Indies Company, it is necessary to understand the almost religious feelings that the people of the Spice Islands had for their clove trees. In The Golden Bough, Frazer describes the attitude of the local people to clove trees in his discussion of tree worship and tree spirits. He states: “In the Moluccas, when the clove trees are in blossom (Fraser apparently believed that the clove of commerce was a seed, rather than a dried bud), they are treated like pregnant women. No noise may be made near them; no light or fire may be carried past them at night; no one may approach them with his hat on; all must uncover in their presence. These precautions are observed lest the tree should be alarmed and bear no fruit, or should drop its fruit too soon, like the untimely delivery of a woman who has been frightened in her pregnancy.”

He also comments: “In some parts of Amboina, when the state of the clove plantation indicates that the crop is likely to be scanty, the men go naked to the plantations by night, and there seek to fertilise the trees precisely as they would impregnate women, while at the same time they call out “More cloves!”. This is supposed to make the trees bear fruit more abundantly.”

The United East Indies Company of Holland decided to reduce clove production in order to create a scarcity and, hence, high prices. Under the leadership

of Jan Pieterzoon Coen, in 1621, the Company sent a force of one thousand armed men into many of the Spice Islands. Every clove tree they found, in every island, except Amboina and Ternate, was felled. This was called the 'extirpation' and many tens of thousands of clove trees were destroyed. Many of the people were massacred, and others were driven into the hills where they died of starvation. These people had traded cloves for rice, and, because they could trade no longer, they starved. The thriving economy of the Spice Islands, which dated from the centuries-old trade with China, was ruined, and this ancient Austronesian culture went into decline.

At the same time, stocks of cloves and nutmeg in Amsterdam were burned, in order to drive up the prices and, for months, the people of this city could smell these spices in their atmosphere. The Dutch maintained their monopoly in cloves and nutmeg for more than a hundred and fifty years. It was finally broken by the French and, specifically, by a Frenchman called Pierre Poivre, who was an eighteenth century governor of Isle de France, an island in the Eastern Indian Ocean, now called Mauritius. The English referred to him as Peter Pepper, or Peter Piper, and they preserved his name in the doggerel "Peter Piper picked a peck of pickled pepper".

Pierre Poivre succeeded in obtaining clove seeds with a secret expedition to the Spice Islands in 1770, and he established cloves in Isle de France. The French then distributed cloves to all their tropical island colonies, including those in the New World. This broke the Dutch monopoly. In 1799, the United East India Company of Holland, which had held the clove monopoly, and had been responsible for the extirpation, went bankrupt.

The British soon got their hands on clove seeds also, and established plantations in Penang, near Singapore, where, however, they did not thrive. The main French production of cloves later developed in Madagascar because hurricane damage was too frequent in the other French production areas.

Perhaps the most romantic and successful introduction of cloves was an Arab initiative in Zanzibar, in 1818, by Harameli bin Saleh, a murderer who had been expelled from the island by the Sultan. He took refuge in the French Indian Ocean islands where he stole clove seeds and took them back to Zanzibar. This earned him a pardon, and the Sultan established a clove plantation on his royal estate at Mtoni. Once seed was freely available, some six years later, the Sultan ordered every landowner to plant cloves, on pain of confiscation of his land.

The Sultanate of Zanzibar and Pemba then became the biggest single producer of cloves, and it also became the source of the best cloves. For many years, its main trading partner was the port of Salem in Massachusetts. It is said that the first American millionaires were made in Salem, by the clove trade, and the beautiful Salem Custom House, which is now a national monument, is an indication of this wealth.

The largest single market for cloves is now in the manufacture of clove cigarettes in Indonesia. From being a clove exporter, this country has now become the largest clove importer because of the demand for clove cigarettes. One part of shredded cloves is mixed with two parts of tobacco to make these cigarettes which are immensely popular in Indonesia, and some of the neighbouring countries, such as Papua New Guinea. Clove cigarettes are extremely pungent, strong, and aromatic. They are not to everyone's taste.

As a final comment on cloves, it is perhaps worth noting that the name gillyflower is given to various plants whose flowers are reputed to smell of cloves. Chaucer, Spenser, and Shakespeare all referred to carnations as gillyflowers. But the name has also been applied to stocks, wallflowers, and other plants. The name gillyflower is a corruption of the Greek name for cloves, *karyophyllon*, which means

"nut-leaf", and was given to the botanical family, which includes pinks and carnations.

Allspice

Allspice or pimento (*Pimenta dioica*), also belongs to the myrtle family but it evolved in Central America, after the separation of the New and Old World continents. Although the aroma is totally different, allspice has an appearance remarkably similar to black pepper. The seeds occur in the same kind of inflorescence and, like black pepper, they are harvested when fully grown but not yet ripe. They are then dried in the sun and their final appearance is just like peppercorns. Indeed, gourmets often add a few allspice seeds to their pepper mills.

It is said that, when he arrived in the New World, Columbus showed black pepper to various groups of natives, hoping to find a supply of it. It seems he was given allspice as the nearest thing to black pepper that the New World could produce, and allspice came to be called Jamaican pepper, or pimento. Conventionally, in English, the dried fruits are now called allspice, while the powdered fruits, the tree itself, and other products from it, are called pimento. Jamaica is the main producer of allspice, and both wild and cultivated trees are common on this island. Allspice fruits literally "grow on trees" with such abundance that no store on the island ever stocks them. If you need allspice, just go out and pick some.

The aroma of allspice is well known in England from the traditional hot cross buns which are cooked only at Easter. Allspice is reputed to have the combined flavours of cloves, cinnamon, nutmeg, ginger, and black pepper, and this is the origin of its English name. Indeed, when these spices are mixed in the right proportions, the mixture is very similar to allspice.

Pimento leaves and bark also contain aromatic substances and are steam distilled to produce pimento oil which is much cheaper than allspice, and is widely used in cosmetics, soaps, pickles, various proprietary sauces, preserved meats and sausages, and the pickled herrings called roll mops. A well known after-shave lotion is scented with it.

When the Spanish arrived in the West Indies, the principle inhabitants of the Greater Antilles were the Arawak Indians. These people populated a number of islands, including the Bahamas, Cuba, Hispaniola (Haiti and Dominican Republic), Jamaica and Puerto Rico. The Arawaks were a social and peaceful people who cultivated maize and cassava, and lived in villages of up to three thousand people.

By the time the Spanish arrived, the Arawaks were suffering from the aggression of the more warlike Caribs, who had already driven them out of some of the Lesser Antilles, such as Trinidad and Grenada. The Caribs adopted much of the Arawak language but referred to it as “the language of women”. This provides a horrifying glimpse of just which Arawak captives the Caribs kept, and which they killed. The Caribs were reputed to be cannibals, and they were the source of references to wild “savages” in the novels of that time, such as “Robinson Crusoe”. Indeed, the island of Tobago, just North of Trinidad, claims to be the original on which Daniel Defoe's description is based.

The Arawak language has added a number of words to European languages. These include barbecue, buccaneer, canoe, hammock, and hurricane. Most of the West Indian islands have European names but Jamaica is an exception. This is an Arawak name meaning “land of wood and water”. Sadly, the Spanish enslaved many of the peaceful Arawaks. They were also highly susceptible to smallpox and measles, and they died out quite quickly. When the British took Jamaica and Barbados from

Spain, in 1655, the Arawaks of these islands were already extinct. Nor have any survived anywhere else.

Vanilla

Vanilla is a sweet spice that is neither hot nor pungent. It is botanically interesting because it is an orchid, and it is the only orchid that is cultivated for purposes other than ornamental blossoms. Being a New World plant from the tropical lowlands of Central America, vanilla was never a subject of the intense rivalries in the spice trade of Europe. However, it was well known to the Aztecs and Mayas, and Mexico still produces the best quality vanilla.

Moctezuma is reputed to have given Cortés cocoa flavoured with vanilla in 1520. However, the Aztecs had no sugar and they more commonly flavoured their cocoa with salt and red peppers. Cocoa (Chapter 15) did not become popular in Europe until it was served sweet, with sugar and vanilla, and with neither red pepper nor salt.

The vanilla itself is a seed pod which is harvested when its growth has finished, but prior to ripening. The pods are ‘cured’ by a process of alternating drying and ‘sweating’. The drying is by exposure to the sun. The ‘sweating’ is by enclosure in air-tight boxes. After about two weeks of this treatment, the pods are a rich, dark brown and have a vanilla aroma. They are then ‘conditioned’ for several months in closed containers in order to develop the full aroma. In some countries, the process is accelerated by dipping the pods in boiling water, or cooking them in ovens, but this produces an inferior product.

All attempts to cultivate vanilla in the Old World tropics failed because, although the plants grew well, they would not produce fruits. This was because the *Melapona* bees, which pollinate the flowers in the New World, are absent from the

Old World. In 1841, Edmond Albius, a former slave in Réunion, discovered how to hand-pollinate vanilla flowers, using a toothpick. Vanilla production in the Old World tropics then boomed and the Malagasy Republic is now the world's largest producer, with a constant danger of over-production and glut. But, to this day, the vanilla flowers in the Old World are still hand-pollinated.

The flavour of vanilla is due to a chemical called vanillin which is now produced synthetically. It was first synthesized in 1874, and it can now be manufactured much more cheaply than the real product. However, the real vanilla has other substances contributing to its fragrance and, for this reason, is superior to any synthetic. Consumers of cheap ice cream may not notice the difference, but gourmets most certainly do.

Nutmeg

Just as a good cook can be recognized by the use of green ginger instead of powdered ginger, and by the use of a pepper mill instead of ground pepper, so a good cook can be recognized by the possession of a nutmeg mill. This machine is as important to the use of nutmeg as a coffee grinder is in the production of fresh ground coffee.

Many delectable flavours, such as those of ginger, black pepper, coffee, and nutmeg, are highly volatile. They quite literally evaporate after a few hours, if left exposed to the atmosphere. Hence the need for freshness of grinding. Nutmeg mills are often hard to come by, and may have to ordered specially. But a nutmeg mill is essential in any good kitchen because freshly ground nutmeg is not only delectable in itself. It is a spice which enhances all other flavours and, for this reason, can be used with advantage in almost any dish, whether sweet or savory. (Nutmeg can be grated

on a kitchen grater but, as the seed is hard, and quite small, this can be dangerous to the finger tips).

Nutmeg originated in the Spice Islands, and its history is almost identical to that of cloves. The Dutch monopoly in these two spices lasted for a century and a half, and this was the Netherlands' golden age. Rich merchants in Amsterdam could afford the beautiful houses that led to a distinctive Dutch architecture. And Dutch art flourished so profusely that, nowadays, the terms ‘Dutch painting’ and ‘old master’ have become almost synonymous.

Eventually, like all other crops, nutmegs were taken to every part of the globe where they might survive. After 1850, Grenada, in the West Indies, began to export nutmeg and eventually became the largest producer. Unfortunately, a hurricane destroyed 90% of the trees in 1955 and, since then, Indonesia, and particularly the original Spice Islands, have been the principle producers.

The nutmeg plant (*Myristica fragrans*) is a tree. The harvested product is a fruit which is about the size of a large plum. The fruit consists of an outer, yellow, fleshy pericarp that splits open when ripe to expose a hard shiny seed case covered in a red, lacinate (i.e., lace-like) skin. Inside the seed case is a single seed which is the nutmeg of commerce, and the lacinate skin provides a second product, the spice called mace.

These two spices contain mostly the same aromatic oils but, nevertheless, they have distinctly different flavours. Traditionally, nutmeg is used in sweet dishes and drinks, while mace is used in savory dishes, and provides the characteristic flavour of many spicy sausages. But either spice can be used in place of the other if necessary. The critical point is freshness and, in this respect, newly ground nutmeg, from a nutmeg mill, is superior to either nutmeg or mace that was purchased as a powder.

Nutmeg does not occur wild, and this suggests that it is of ancient domestication, because the wild trees were probably exploited to extinction, and only cultivated trees were preserved. The tree is propagated from seed and the progeny are very variable in their yields. A further problem is that the species is dioecious (Greek = two houses). This means that the two sexes occur as separate male and female trees.

Males and females occur with equal frequency and they cannot be distinguished until the trees produce flowers for the first time, some 5-8 years after planting. As only one male is needed to pollinate every ten females and, as only the females produce fruit, the majority of the males must be removed and replaced with new seedlings. Unfortunately, half of these will also be males and some of the females will be poor yielders that also have to be removed. It clearly takes time to establish a highly productive nutmeg orchard. The obvious answer is vegetative propagation of high yielding female trees by cuttings but, unfortunately, nutmeg cuttings do not root easily.

Cinnamon

Cinnamon was nearly as important as black pepper in the various monopolies of the spice trade. As described in the chapter on coffee (Chapter 14), cinnamon was known to the ancient Romans who, however, remained ignorant of its source. It seems that this ancient cinnamon was produced in the islands of modern Indonesia, and that Austronesians took cinnamon quills, along with planting material of rice (Chapter 7), bananas (Chapter 19) and an Asian species of yam, in their large double canoes straight across the Indian Ocean to Madagascar. From there it was taken to mainland Africa, and then overland to Alexandria and the markets of Rome.

Many fabulous tales were told in antiquity to protect the secret of cinnamon's source, and Herodotus even quotes some of them. One of Herodotus' stories, stating that it was carried “on open rafts across vast tracts of water without rudder or sail” was close to the truth. Ancient Egyptian and Biblical records suggest that cinnamon came from Africa, probably from the general area of modern Somalia, known as the “Horn of Africa”, and believed by some archaeologists to be the unidentified land that the Egyptians called Punt.

This historical problem is complex and it is seriously confounded by the fact that there are various trees that have aromatic bark, often described as cinnamon, or as the closely related spice, cassia. However, none of these trees occur in either Africa or Arabia. Many of them occur in Sri Lanka and India and, in antiquity, they were cultivated in Assam and China. They may possibly have been taken to Europe on the silk route, which started in Central China, and went overland, south of the Gobi desert, and north of the Himalayas, to Kashgar, Tashkent, Samarkand, and Baghdad.

Our problem is that we do not really know which bark it was that the ancients called cinnamon. We do know that the Romans later established their own shipping route along the South coasts of Arabia and Persia to India, where they could at least purchase cinnamon from merchants, even if they did not see it growing. Eventually, these traders discovered Sri Lanka and actually saw the trees, now called *Cinnamomum zeylanicum* which produce the best cinnamon.

Cultivated cinnamon is never allowed to develop into a normal tree. The shrub is repeatedly cut back to ground level and it then produces many young shoots which are harvested. The bark is peeled off and dried to make the cinnamon ‘quills’ of commerce. Cinnamon is used mainly as a sweet spice in cooking but it is also added to curries, incense, toothpaste, perfumes, and cosmetics.

Chapter Eleven

Potato

The potato is now the fourth most important food crop in the world, after wheat, rice and maize. But this importance has developed only during the last two centuries. Before that, the potato was never a major staple in the sense of this book, principally because of the difficulty of storing the potato tubers, which rot easily. Consequently, the potato never engendered an important civilisation, and the growth of cities. However, since the end of the eighteenth century, potatoes have had a major impact on both the food production, and the population size, of most temperate countries. This crop accordingly demonstrates just how important the carrying capacity of the environment still is, in spite of all the modern marvels of our technology.

Pre-Colombian Potatoes

The home of the potato, in the Andes, is at altitudes that are too high to grow maize. The natives of this area, who still grow these potatoes, discovered how to store them at a very early date. The tubers are laid on the ground at night, and they then freeze. During the day, the thawed out potatoes are squeezed with people's feet to expel water, and they are left exposed to the sun to dry. The process is repeated for several days to produce a dried tuber called *chuño* that can be stored like a cereal. Both the fresh and the dried tubers became the staple food of these high altitude people. This happened at an uncertain date which, however, may have been as early as 2000-5000BC, and at about the same time as the domestication of the llama.

In its centre of origin, therefore, the potato could be stored, and it should have been a major staple in the sense of this book. That is, it should have led to the growth of cities during the several millennia of its cultivation. In practice, it did not, for reasons that are far from clear. It is possible that the high altitude potato environment was altogether too cold, and too hostile.

These high altitude potato growers carried on an active trade with people at lower altitudes who grew maize and other crops. For this reason, *chuño* was known to many of the maize growers, and it was prized. But it was never more than an adjunct to the major staple that was maize. And it was maize, not potatoes, that permitted the growth of all the cities of South America.

Without exception, the cities and civilisations of South America originated at altitudes that were suitable for maize cultivation, and unsuitable for potato cultivation. There can be no doubt that it was maize, not the potato, that was the major staple that permitted the growth of civilisation in South America. The potato itself did not support the growth of a single city.

For example, the huge capital of the Chimú people, called Chan Chan, was located on the Pacific Coast, and was based on the cultivation of maize. This city covered fifteen square kilometres. The Chimú nation embraced some 1,600 kilometres of Peruvian coastal lowlands, and it lasted for seven hundred years, until it was conquered by the Incas in 1476. This was only a few decades before the Spanish marauding adventurer, Francisco Pizarro, in his greed for gold, destroyed both the Inca Empire, and the entire civilisation of South America.

We can, perhaps, attribute the Inca empire to the potato. This empire was acquired by conquest by high altitude people who originated near Lake Titicaca, and who grew potatoes, but not maize. Their achievement was their conquest, but they had no cities. However, in terms of cultural evolution, and civilisation, conquest

cannot be equated with the growth of cities. The Vandals, after all, conquered Rome, and this was followed by the Dark Ages..

The Incas were conquerors first and foremost. They were also very efficient rulers of conquered people. But it was only as a result of their conquests that they obtained both a major staple, and the low altitude land to grow it in. Although the Incas valued, preserved, absorbed, and copied the civilisation of their subject peoples, they did not originate any of these cultural developments themselves.

The Inca capital city of Cuzco, and the great Inca temple of Machu Picchu, were built at altitudes too high to grow maize and, at first sight, they might have been based on the potato. But, in fact, the Inca empire had a very efficient system of military roads, and large quantities of maize and other storable foods were transported by llamas, or on people's backs, to regional granaries. The Inca cities, and the Inca civilisation, were thus based on maize. As happened in early cities throughout the world, Inca taxation was in the form of grain and *corvée* labour, which the Incas called *mit'a* labour. Cuzco and Machu Picchu, were both built with *mit'a* labour coming from lower altitudes. And these cities were fed mainly with maize that also came from lower altitudes.

Origins of the Potato

The botanical family *Solanaceae* occurs on both sides of the Atlantic. But, because the two halves of the family were separated by continental drift, and the formation of the Atlantic Ocean, some sixty five million years ago, entirely different species evolved in the New and Old Worlds. It so happens that, except for the eggplant (*Solanum melongena*), which originated in India, all the domesticated species of this family are New World species which accordingly remained unknown in the Old World until the Spanish discovery of the Americas. These domesticated

species are potatoes (*Solanum tuberosum*), tomatoes (*Lycopersicon esculentum*), tobacco (*Nicotiana tobacum*), red peppers, sweet peppers, and chillies (*Capsicum* spp.), , tree tomato (*Cyphomandra betacea*), cape gooseberry (*Physalis peruviana*), and the Mexican green tomato (*Physalis ixocarpa*).

It so happens also that many of the Old World species of this family are poisonous and, when these new food crops arrived in Europe, they were received with suspicion for this reason. The most poisonous of the European species were the deadly nightshade (*Atropa belladonna*), henbane (*Hyoscyamus niger*), thorn apple (*Datura stramonium*), bittersweet (*Solanum dulcamara*), and garden nightshade (*Solanum nigrum*). The poisonous nature of these plants was well known all over Europe, and the potato was often associated with them. The potato was also associated with tobacco, which was greatly disliked by many people in those days.

The cultivated potato is a native of the high mountains in the Andes of Bolivia, Peru, Colombia, and Ecuador. It likes a cool climate and, for this reason, it adapted well to temperate agriculture. However, it is also an equatorial species, and it is sensitive to day-length. The equatorial regions have approximately twelve-hour days and nights throughout the year, and they never experience the long days of a temperate summer. This meant that the potato originally introduced to Europe required twelve-hour days and nights to initiate tuber formation. It was what botanists call a ‘short-day’ plant.

These short day conditions occur in temperate countries at the time of the spring and autumnal equinoxes. This meant that, in Europe, tuber initiation would occur only in late September, and the plants would be ruined by frost before the tubers were mature. For this reason, potatoes remained little more than a herbalist’s curiosity for some two centuries in Europe.

After about two centuries of mainly unconscious selection by people in Europe and, no doubt, an element of natural selection by climate, these tropical potatoes changed into a 'day-neutral' plant. They were then able to set tubers in the long days of summer, and the crop could mature before there was any risk of frost. In addition, the tubers themselves became fewer and larger, and they had shorter stalks that made harvesting easier. They also had a better shape, with less deep eyes, and this made peeling easier. And the plants themselves were bigger, with larger, more productive leaves.

This domestication was completed in the late eighteenth century and, suddenly, potatoes boomed. They became a major food crop in Europe, North America, and other temperate areas. It is ironic that this tropical crop, which has never been very important in the tropics, is now one of the most important food crops in the world, but only in the temperate regions. This crop has also attracted an immense amount of scientific research, but this too has been largely confined to the temperate regions.

Ireland has such mild winters that the short day potatoes could be cultivated there without excessive losses from frost. Potatoes consequently became the staple food in Ireland much earlier than the rest of Europe. One of the principle varieties in Ireland was called *Lumpers*, and it was very similar to the original introduction from Colombia. For this reason, was a short-day potato which matured very late in the year, and it was occasionally spoiled by an early frost. This variety is now extinct, for reasons that will be related in a moment.

Nomenclature

There are two different crops called potato. The first of these to reach Europe was the sweet potato (*Ipomea batatas*). It was taken to Spain by Columbus who used its Caribbean name, *batatas*. The sweet potato is an essentially tropical plant and it

never flourished in Europe. However, it gave its name to other potato plant, which also forms edible tubers. *Batatas* was corrupted into the Spanish word *patata* and, from there, into the English word *potato*. In its turn, the English word is often corrupted into *tater*. A synonymous Spanish name is *papas*, which is the original name in the Quechuan language of the Incas. The term *papas* is less liked in Spain because, by sheer coincidence, it is the same as the Spanish words for father and Pope.

In Italy, the potato was known as *tartuffo*, meaning a truffle. This Italian word was corrupted into the German *kartoffel*, which is also the term used in Poland and Russia. In the English language, the term 'Irish potato' is often used, particularly in America, to distinguish it from the sweet potato.

Both *spud* and *murphy* are slang names for the potato and, in Britain, anyone whose name is Murphy is liable to be nicknamed "Spud". The word spud apparently derives from a special kind of digging tool that was originally used to harvest potatoes. And Murphy has an obvious Irish connotation.

The term 'hot potato' comes from the fact that a hot potato was often used to keep the hands warm, usually held inside a muff. In the late seventeenth century, street vendors would often sell hot potatoes during cold weather for this reason. And, in Staffordshire, they used to make 'potato bottles' out of pottery, and in the shape of a potato. These could be filled with hot water and then used for the same hand-warming purpose. In the days before nylon, holes in stockings were common, and were often called potatoes, because the heel seen through the hole resembled these tubers.

Introduction to Europe

It was the Spanish who introduced potatoes to Europe, from the Caribbean shores of Colombia, in about 1570. Sadly, the popular English legends about potatoes having been brought to England by Sir Walter Raleigh, or by Sir Francis Drake, are not true. There may have been a few other introductions from the same area, but there were not many, and the genetic base of potatoes in Europe remained very narrow. Potatoes were taken to North America from this narrow genetic base in Europe.

In Europe, the new potato crop was often received with suspicion because of its poisonous relatives. But there were other grounds for suspicion. The Scots, for example, objected to it strenuously on the grounds that it was not mentioned in the Bible. There was also a widespread belief that potatoes caused leprosy. This was a curious conclusion, in view of the fact that leprosy *is* mentioned in the Bible. And the Scots apparently did not object to other New World or tropical crops that were also unknown to the Bible.

The people of Europe were slow to take to the potato, quite apart from any problems of long days. In 1619, Gaspard Bauhin wrote that, in Burgundy, potatoes were known as 'Indian artichokes' and it was forbidden to eat them on the grounds that they caused leprosy. There is a persistent but unconfirmed legend that cultivation of the potato was legally forbidden by the Parliament of Besançon in 1630.

Most early writers believed that the potato was an aphrodisiac, and caused lust in both men and women. They also reported, equally incorrectly, that it caused flatulence. This, after all, was an age when superstitions ran riot and harmless old women were burnt as witches. The potato was also thought to be responsible for scrofula (i.e., tuberculosis of the bones and lymphatic glands). In Prussia, it was believed that the potato gave rise to scrofula, rickets, consumption, and other evils. It needed all the influence of Frederick the Great to break down this superstition.

Impact on Europe

During the eighteenth century, Europe was constantly on the verge of famine and starvation, and food shortages were both common and acute. Frederick the Great, King of Prussia, for example, modernised his country's agriculture with land enclosure, and incentives to individual farmers. He also passed a law that every farmer should grow a plot of potatoes. At first, most Prussian farmers did not know what to do with this crop, and a few actually died from attempting to cook and eat the poisonous leaves and fruits.

Potatoes make an excellent substitute for bread, and one that is much cheaper, and easier to produce. It is an interesting speculation that, if the French had been cultivating potatoes in quantity, in the late eighteenth century, the shortage of bread in 1789 would not have mattered, and the French Revolution might never have happened. Marie Antoinette would have been in a position to say "Let them eat potatoes", and she would not have been remembered as the stupidest woman in history.

At that time, northern Europe depended entirely on its traditional crops for vegetable foods. These, of course, were the four cereals (wheat, barley, rye, and oats), and peas and broad beans. In addition, haricot beans had been recently introduced from the New World. There were also various vegetables such as carrots, parsnips, and spinach. However, the total production of these crops was only just enough to feed the population. Northern Europe had reached the limit of the carrying capacity of its environment. The introduction of potatoes changed this situation dramatically, just as the introduction of maize had impressively increased the carrying capacity of the environment in southern Europe (Chapter 8).

The increase in the carrying capacity of the northern European environment had very profound consequences. As had happened again and again throughout history and pre-history, the population increased until the limits of the new carrying capacity were reached. And it even increased *beyond* that carrying capacity. Europe became a people-exporting area on a major scale. European emigrants populated much of the Americas, and much of Australasia.

The increase in population that resulted from the use of potatoes had certain other, quite different, and totally horrifying, consequences in Europe. We have seen (Chapter 6) that barbed wire and the machine gun transformed war and that, as a result, eight million soldiers died during World War I. This kind of slaughter was impossible in earlier wars because, quite apart from the wire and the guns, such numbers of young men simply did not exist. The slaughter was possible only because of the greatly increased size of population, made possible by the increased carrying capacity of the environment of Europe.

This is something that the ‘right to life’ advocates overlook. It is surely better not to be born at all, than to be born to an early and horrible death. In the case of these soldiers, their deaths were due to war. But starvation due to over-population is just as horrible. And the horrors of growing up as an unwanted and unloved child are little better.

During World War II, a total of some forty million people were killed, with about half of these deaths occurring in the Soviet Union. The country that lost the greatest proportion of its people was Poland, which lost 18% of its population. Losses of this magnitude could not easily have been borne, and the populations could easily not have recovered, without the increased carrying capacity of the environment due to the potato. It would be a mistake to suggest that two world wars, their slaughter, and

the holocaust, were actually caused by population increases. But there can be no question that the sheer numbers of victims were a consequence of these increases.

Perhaps the first effect of the increased food provided by the potato, and the increased population, was that cheap labour became available in great numbers. In terms of exploitation, this was the modern equivalent of *corvée* labour, except that the labourers were numbered in their millions rather than their thousands. It was then, and *only* then, that the industrial revolution could develop. Plentiful cheap labour permitted coal to be mined in large quantities for steel production, and for running the new steam engines. Steel was produced in ever increasing amounts for building railways, bridges, steam engines, ships, and machinery of many kinds.

This was an entirely new social phenomenon, and people simply did not know how to cope with it. In particular, the cheap labour was abused quite ruthlessly. It was the "dark satanic mills" of England that prompted Marx and Engels to think about the evils of money, and the mirage of communism.

The combination of Darwin's theory of evolution, and the poverty engendered by the population increases, led to that iniquitous doctrine called Social Darwinism. This false concept, based on a complete misunderstanding of Darwin's theory, assumed that "survival of the fittest" applied *within* a social species, and that it also applied to the growth of culture. The fact that the children of rich parents received an expensive education, while the children of poor parents received no education at all, was taken as proof of the rich children's' blue blood, and their genetic superiority. And the appalling squalor of the exploited labourers was taken as proof of their genetic inferiority. Social Darwinism was the very antithesis of the charity, altruism, and cooperation that are among the essential criteria of human cultural growth.

Social Darwinism reached its climax of horror with the Nazis, and their total, blind conviction of their own genetic superiority, and their equally blind, and equally

strong, conviction of the genetic inferiority of all others. Since World War II, there has been a conspiracy of silence about Social Darwinism. It is a *taboo* subject, too dangerous even to mention. But we must mention it, and recognise it, because it persists, in a mild form, to this day. It shows, for example, in the quite common idea that people who never developed a great civilisation were (and are) genetically inferior. This is a pernicious and insidious idea. And it is also a false idea. The principle message of this book must be repeated. It is quite simply that the great civilisations each depended on the occurrence of one of the three kinds of wild grass that were capable of being domesticated into a major staple.

Consider an alternative scenario. If the wild precursors of wheat, rice, and maize had originated, and had been domesticated, in, say, North America, South Africa, and Australia, respectively, *these* would have been the centres of ancient civilisation. And highly sophisticated, indigenous people from these centres would now be studying the picturesque and *interesting* (don't you know) hunter-gatherer societies of Europe.

The Great Potato Famine

One of the more important aspects of the potato in recent human history has been in its vulnerability to pests and diseases. Crop scientists have a special way of defining the word *vulnerability*. For them, this word means that a crop is susceptible to a foreign pest or disease that is *absent* from the area in question. The crop is vulnerable because that foreign pest or disease might be inadvertently introduced at any time. When it is introduced, the crop is liable to be devastated, and a situation that was one of only potential damage, becomes one of actual damage. Crop vulnerabilities vary greatly in their importance, but the serious ones are very serious indeed.

Potatoes in northern Europe boomed in areas where wheat grew only poorly, or not at all. Problems with wheat were at their most marked in Ireland, and in the general region of eastern Germany, Poland, and western Russia. In all these areas, potatoes became the staple food. And, in most other parts of northern Europe, potatoes became the staple food of the poor, particularly the poor who were living in the new urban developments of the industrial revolution. In the ecological terms of this book, there was a major increase in the carrying capacity of the environment of northern Europe. And this was followed by a major increase in the total population of northern Europe. But, lurking ominously behind all this growth was the hidden fact of the vulnerability of the potato to foreign pests and diseases.

In 1845, an important part of this vulnerability was manifested. A disease of wild potatoes in Mexico, now called blight, and caused by the microscopic fungus *Phytophthora infestans*, had been carried by potatoes in a ship's stores to New York, where it became established. Shortly after that, the disease had been carried by another ship to Europe. For the first time in history, the world experienced a really devastating plant disease. Many of the potato crops of North America and Europe were reduced to a black stinking mush, with nothing but dead stalks sticking up from the ground. Below ground, the tubers were rotten. It was at this point that the science of plant pathology was born, and the decade became known as "The Hungry Forties".

As we have seen, famines were common in Europe until the widespread use of potatoes. This was because the population density had exceeded the carrying capacity of the environment. Many of these famines were triggered by war, and by the destruction of crops or, more frequently, by the fact that war prevented the crops from being planted in the first place, or from being harvested. It was normal for members of the poorer classes to experience starvation at least once in their lives. Not infrequently, it was starvation that ended their lives. Consequently, for about half a

century in Europe, potatoes were a boon that put an end to famines. Until, that is, the blight arrived.

The famine in Ireland is the best documented in English, and is the one described here. But it should be remembered that closely similar catastrophes occurred in other countries, wherever the potato had become a major component of the diet. This was particularly true in the huge area of poor soils that included and surrounded Poland. To this day, this region still has the highest *per capita* consumption of potatoes in the world.

In Europe, the disease was first seen in northern France and Belgium. Within a few days, it was recorded in England, in the Isle of Wight. Shortly after that, it was found in Ireland where most of the earlier potatoes had already been harvested. But the blight did great damage to the late potato varieties that were still growing. About half of the total crop in Ireland was destroyed.

Ireland has always been a poor country. This poverty is not the result of any deficiency in the people who populate this beautiful island. It is a result of the environment. Ireland is warm, because of the Gulf Stream, and it is also very wet, because it catches much of the rain moving into Europe from the Atlantic Ocean. It is consequently very green. In theory, this lush land should be an ideal place in which to produce food, but it is not. Ireland is too wet for wheat which can be grown only with difficulty, and with considerable risk of loss if it is raining during the period of harvest. The wet weather also aggravates the damage caused by the various pests and diseases of wheat. Much the same is true of barley, oats, and rye. Famines, and the epidemics of human diseases that are associated with famines, were common throughout Irish history.

This situation was exacerbated by religious wars which all stemmed from the fact that Henry VIII, in 1534, had broken with Rome and closed the monasteries. The

Irish remained faithful to Rome and they suffered for their faith. Oliver Cromwell was a strict Calvinist who detested the Catholics, and he waged ruthless punitive campaigns in Ireland. His behaviour could have stood as an early model for the policies of Hitler in Poland and Russia. When Ireland was 'pacified', Cromwell gave the best land to English Protestants who became the landed gentry. Most of the native Irish then became landless 'cottiers'. That is, they rented some land from an English landlord. They lived on this small plot of land where they grew potatoes to feed both themselves and, perhaps, a pig. They paid their rent with free labour and, occasionally, with money from the sale of a pig. The amount of the rent was decided by auction among landless people who needed land. And their labour was usually assessed at about half the going rate for paid labourers. About once a year, the debts between landlord and tenant would be calculated, and the balance either way was struck. If any money was left over, the cottier was also expected to pay his tithe to the Catholic priest. But, if the cottier owed money to his landlord, and could not pay, he was evicted, with all his family.

These cottiers were poor in the extreme. They lived in hovels built of turf and roofed with thatch. Each cabin had an open fire in the middle of the dirt floor, but furniture and other amenities were usually lacking. Their clothing was meager and consisted of rags. Food shortages were a recurring problem, usually because the potato crops were damaged by excessive rain, an early frost, or poor storage. Throughout their lives, these wretched people knew only one real pleasure, and this was the pleasure of sex. Combined with the abundance of potatoes, this inevitably led to population increases. It was the old, old story. Given an increase in the carrying capacity of the environment, the population increased until it exceeded that new carrying capacity. No accurate figures are, or ever were, available. But, it is estimated

that, between 1800 and 1840, the population of Ireland doubled, from four million to eight million. And then disaster struck as the potato crops were destroyed by blight.

This kind of disaster had not been experienced in Europe since the black death. The great plague of 1665 killed nearly 100,000 people in London, and possible as many again in the rest of the country. But the plague was not accompanied by famine, and an all-embracing poverty. The Irish famine, amongst poverty-stricken people, was probably the first occasion in English history when the government was compelled to plan and organise relief measures on a large and comprehensive scale. The general lack of experience in relief work explains many of the blunders, and it would be unjust to judge these blunders according to the standards of our own day. There was also a total lack of medical knowledge concerning epidemic diseases, and the knowledge of human nutrition was rudimentary. This ignorance also should not be judged according to our standards of to-day.

It must be remembered also that these were the days when people really believed in social classes. The upper classes were superior. And the lower classes were inferior. This was obvious, damn it. You only had to *look* at them. The lower classes were stupid and incompetent. And the Irish cottiers were the lowest of the low. If they were otherwise, they would have taken steps to improve their lot. And they would have done this years ago. That *proved* it. Indeed, there was considerable doubt whether it was even worthwhile trying to help useless people like that.

There was a famous surgeon, one Alfred Smee, a Fellow of the Royal Society, who was of the opinion that the potato was evil. It had done nothing, in his view, but produce millions of paupers. He recommended a policy of *laisser faire*. Left alone, he claimed, the problem would solve itself. It was Smee's belief that the interference of the government was stupid. By providing famine relief, this excessively charitable

government had actually prevented the Irish problem from being settled once and for all, by Providence.

Quite apart from this kind of prejudice, there were many genuine blunders. Perhaps the worst blunder was an infamous clause in the Poor Relief Act, which said that any man who possessed, or in any way occupied, more than one quarter of an acre of land, was not eligible for relief. This meant that the cottiers had to vacate their plots and, hence, their cabins before they could claim famine relief. They were thus presented with a horrible dilemma. They could stay on their land, and in their cabins, and starve. Or they could leave their land and their homes in order to claim relief. But, once off their land, they could no longer help themselves, they had nowhere to live, and nowhere to grow crops. They were totally dependent on government housing and government food.

Without potatoes, the cottiers who remained on their land were too weak to work in order to pay their rents. Many landlords evicted such tenants, who then had no choice but to go to the poorhouses. However, the poorhouses were full, and rioting and looting often broke out when the poor and the starving were turned away. The landlords were often heartless in the extreme, and their usual method of evicting tenants was to demolish their cabins.

Dead bodies would be found on the roadside. In some towns the dead could not be buried, because there were so many of them. There were many deserted cabins, often containing unburied corpses, and everywhere there was a spirit of utter hopelessness. Small traders were ruined and were often in no better state than the cottiers.

Entire families were left without food, and without shelter. The first winter of the famine was unusually cold, and it snowed as early as November. It was then that the “famine fever” began. This was probably typhus or cholera, or both, and it killed

many more than the actual food shortages had done. The nature of infectious diseases was not understood in those days, and the diseases began to invade the houses of the middle and upper classes.

Captain Wynne, a local inspector, wrote to the authorities on Christmas Eve, 1846, about "...women and little children, crowds of whom were to be seen scattered over the turnip fields, like a flock of famishing crows, devouring the raw turnips, and most half-naked, shivering in the snow and sleet, uttering exclamations of despair, whilst their children were screaming with hunger." It is estimated that rather more than ten percent of the population of Ireland died as a result of the famine. Another twenty percent emigrated, mainly to America.

A few of the landed gentry assumed some responsibility for the welfare of the poor and the starving, and they created work for them. The most common work consisted of the building of stone walls around country estates. Many of these walls still exist and, to this day, they are known as "famine walls". The government also provided work, usually building useless roads that went from nowhere to nowhere, and useless canals that were never even filled with water.

Lord George Bentinck proposed to Parliament that railway construction should be started in Ireland. Railways would have been very useful, and this work would have provided cash wages for honest work to many men. Bentinck proposed 1,500 miles of track, and the employment of 108,000 men. At that time, there was a railway building boom. England and Scotland had 2,600 miles of track, but Ireland had only 65 miles. Parliament refused.

In March of 1846, the government began importing yellow maize from America. This food was chosen, first because it was cheap, and second because it could be distributed in Ireland without too much opposition from the Irish corn merchants. Naturally, it would never do if the government's charitable measures were

to dislocate the trade in wheat and oats. Trade was sacrosanct. However, the people hated the yellow maize. It was a food unknown to them, and they often did not even know how to cook it. The government later set up soup kitchens, but these often dispensed maize porridge rather than real soup.

The cottiers mostly grew a very old variety of potato, already mentioned, called *Lumpers*. The mere fact that this variety had apparently been cultivated for some 150 years without renewal of seed stocks is remarkable. No modern potato variety could be cultivated in this way, without the use of expensive seed tubers, certified free from tuber-borne diseases. *Lumpers* must have been very resistant to all the potato diseases. Except blight, that is. Indeed, it was highly susceptible to this new-encounter disease. It was also a very late variety and, for both of these reasons, *Lumpers* suffered severely, because the blight epidemics become increasingly severe as the growing season progresses. The *Lumpers* variety quickly became extinct, and it was replaced by earlier and more resistant varieties. It is probable that the extreme susceptibility of the *Lumpers* was in a large part responsible for the severity of the blight in Ireland. And its replacement by more resistance varieties was responsible for the decline in the severity of the blight epidemics after 1846. But it was the cottiers who grew *Lumpers*, and it was they who suffered the most.

The famine also had some unexpected side-effects. It might have been thought, for example, that the fishing industry of the west coast of Ireland would have boomed, and done much to save lives. Instead, it collapsed, partly because the poor could not afford to pay for fish, and partly because the fishermen also ate potatoes. Many of them were compelled to pawn or sell their tackle to meet their immediate food needs.

By July 1847 there were 3,540 soup kitchens in full operation. Cooked food was given to 3,000,000 people every day. The ration was 1.5lbs bread, 1lb biscuits,

meal or flour; alternatively, one quart of soup thickened with meal, with a quarter ration of bread, biscuit, or meal. In October 1846, 114,000 men were employed on relief work and, by January 1847, the number had grown to 570,000. Public donations in Britain reached £1.5 million. In addition, the people of the United States and Canada sent large consignments of maize and other provisions, as well as clothing.

The work of the Society of Friends (i.e., the Quakers), in both the United Kingdom and the United States, was beyond praise. They initiated active, practical relief by trying to establish alternative crops, mainly vegetables such as carrots, turnips, and parsnips. And they refurbished the fisheries. But, even here, there was religious dissension. The Quakers, of course, were Protestants, and they often converted Irish Papists, who became known as “soupers”, because they took soup from the Protestant tempters.

The famine ended in Oct 1847 when abundant corn harvests, and a good crop of potatoes, although on a much reduced area, made further relief unnecessary. And, by then, of course, much less food was required, because the population of Ireland had been reduced by about a third, because of emigration and death.

The Repeal of the Corn Laws

The Irish famine precipitated an end to centuries of Whig domination of English politics. The Whigs had come to the fore after the revolution of 1688, when the power of the Crown was subordinated to that of Parliament. The great Whig families had mostly started their climb to fame and fortune at the time of the black death, in the fourteenth century. About one third of the population of England had died of this disease, leaving much land unowned and unoccupied. This was the time of the land enclosures, and the Whig families grew rich as they amassed huge estates

on which they built stately homes. Their wealth came from agriculture, and chiefly from the rents they received from tenant farmers on their estates.

Much of this agricultural wealth depended on the corn laws which imposed import tariffs on foreign corn. These laws maintained both the Whig wealth, and the high price of grain, and they were, in fact, a tax on food. Lord John Russell described the corn laws as "the blight of commerce, the bane of agriculture, the source of bitter divisions among classes, and the cause of penury, fever, mortality, and crime amongst the people."

Robert Peel was prime minister at the time of the Irish famine. He had become famous for creating the first police force and, to this day, British policemen are named after him, and are known as "bobbies". In the early days, they were also known as "peelers". Peel had been elected on a promise to maintain the corn laws. But he had later become converted to the Manchester School of Free Trade. The Irish famine gave him an excuse to repeal the corn laws. His repeal bill was passed by both Houses and it was immediately followed by the defeat of his government by angry members of parliament. Peel resigned, but he had initiated a new era of free trade that was to flourish until World War I.

When the corn laws were repealed, the price of all agricultural commodities declined and many tenant farmers in England could not pay their rents. This was also the time of the industrial revolution, and many agricultural workers, and tenant farmers, were migrating to the industrial towns. Consequently, the combination of the blight epidemic and the repeal of the corn laws led to a financial crisis. The English government had spent £33m on Irish famine relief, and this had led to a drain on the gold reserves. The national revenue fell, and industry was hampered by a rise in the interest rate from 3% to 9%. Labour also suffered and, as wages fell, there were strikes and lockouts.

There had been a lot of railway construction during the 1840s, in both Britain and continental Europe, and this had led to a general shortage of capital, because of too much reckless and dangerous borrowing. In 1846, with the total failure of the Irish potato crop, corn prices more than doubled, and there had been wild speculation. In 1847, the blight was much less severe, the corn laws were repealed, and corn prices fell. A major financial crash followed, and a wave of bankruptcies swept over the Stock Exchange.

The Whig families never really recovered from these disasters. They persisted in their stubborn belief that the best investment, and the safest form of wealth, was in the ownership of land. But times were changing with the industrial revolution, and industry was replacing land as the basis of real wealth. It was the industrialists, represented by the Liberal Party, who now gained long-term political power at the expense of the Whigs.

With his usual succinct brevity, the Duke of Wellington, summed up the repeal of the corn laws, the fall of Peel's government, and the blow to the Whigs. He said "Rotten potatoes have done it all - they put Peel in his damned fright, and his country gentlemen looked on aghast".

Bordeaux Mixture

The story of Bordeaux mixture will be found in Chapter 20. What matters here is that this fungicide controlled potato blight just as effectively as it controlled the downy mildew of the vines. The effect on potato cultivation was wonderful, but the effect on potato breeding was little short of disastrous.

Breeding Potatoes for Disease Resistance

I have written elsewhere (*Return to Resistance* available as a free download at www.sharebooks.ca) of how the resistance to blight went up and down like a yo-yo, during some two centuries, on a forty-year cycle which, curiously enough, is the normal active career of a scientist.

The potato host and the blight parasite evolved on different continents, and they were brought together by people. This makes blight a new-encounter disease. And it was a very damaging disease because the potato host had minimal resistance to the blight fungus. Consequently, until 1845, the potato crops were vulnerable to blight. In 1845, this vulnerability was manifested and, for the next forty years, there was extreme selection pressure for horizontal resistance to blight. Sufficient resistance accumulated for potatoes to be economically cultivated without any fungicidal spraying. Then, in 1882, Bordeaux mixture was discovered and, by 1885, it was being used on the potato crops. It was also used by the potato breeders to protect their delicate seedlings from this disease. The selection pressure for blight resistance changed from being positive to being negative. For the next forty years, resistance was lost until scientists were jolted out of their complacency by World War I. Rifles and guns require copper for their brass shell cases, and Germany was acutely short of copper. Without copper, Germany could not make Bordeaux mixture, her potato crops could not be sprayed, and the losses from blight led to food shortages that forced her to surrender. This disease of potatoes had a strategic significance and various countries decided to breed blight-resistant potatoes that did not require fungicidal spraying. For the next forty years, potato breeders attempted to control blight with vertical resistance (Chapter 2). They failed, because vertical resistance is temporary resistance. But, in the process, they lost even more horizontal resistance. Crop scientists should then have turned to horizontal resistance, but they did not.

They preferred to rely on chemicals and, in this process also, they lost even more horizontal resistance. This is where we are today. And we *still* spray our potato crops. For closely similar reasons, we also spray them with insecticides. And we waste a fortune every year on expensive seed tubers, certified free from disease. Given proper breeding, none of these expensive pesticides or seed certifications should be necessary.

Approximate Years	**Cause of Selection Pressure**	**Type of Selection Pressure**	**Blight Resistance**
Up to 1845	Pre-blight	Negative	low horizontal resistance.
1845-1885	Post-blight	Positive	gain of horizontal resistance.
1885-1925	Bordeaux mixture	Negative	loss of horizontal resistance.
1925-1965	Mendelian school	Positive for VR Negative for HR	gain of vertical resistance; more loss of horizontal resistance.
1965-present	Fungicides	Negative	further loss of horizontal resistance.

Potato breeding began at an early date. In 1788, William Marshall gave a full description of the methods employed by Yorkshire farmers to produce new potato varieties. This Yorkshire breeding had only one object, and that was to breed for resistance to the virus diseases which accumulated within each potato clone. The nature of viruses was not to be discovered for another century and a half, but the effects of these potato viruses were all too obvious two centuries ago. Virus-infested clones were ruined.

It had already been discovered that virus-diseased potatoes never recovered. However, it had also been discovered that seed tubers brought from the Yorkshire Moors, or from Scotland, grew much more vigourously than seed tubers obtained from degenerate stocks. This was because the virus-carrying insects were absent from these areas, and potatoes grown there remained virus-free. This was the beginning of a dichotomy in scientific thinking that continues to this day. Scientists had a choice

between two entirely different methods of controlling potato viruses, and they chose the easy one. It was also the expensive one, and the wrong one.

One method of controlling viruses is to breed for resistance, and the other is to use virus-free stocks of seed tubers. Those Yorkshire breeders of two centuries ago had the right idea. They were breeding for resistance. But this was a difficult task, particularly when the nature of polygenic inheritance is not understood. It is also difficult to distinguish between a potato that is virus-free, for the simple reason that it has not yet become infected, and one that is resistant. The only way to breed for resistance is to infect every new seedling with the virus, and to keep only the most resistant ones. This process must be repeated for some ten to fifteen generations of recurrent mass selection. The whole process must also be repeated for each of the major viruses, and some of the other tuber-borne diseases. This is a fairly large undertaking, in terms of plant breeding. But, once it was completed, there would be little further need for certified seed tubers, which are probably the biggest single cost in commercial potato production..

At the beginning of the twentieth century, Mendel's laws of inheritance were recognised, and the science of genetics came into existence. Unfortunately, conflicts among the geneticists themselves led to the domination of plant breeding by the Mendelian school who favoured the breeding techniques that work with single-gene characters. When single-gene resistance (i.e., vertical resistance) is employed, it has three serious disadvantages. First, it is almost invariably temporary resistance because the disease is able to produce new strains that can overcome it. Second, it requires the discovery of genes for resistance. If these genes, this "source" of resistance, cannot be found, the breeding cannot commence. And, third, horizontal resistance tends to be lost during the process of breeding for vertical resistance.

It so happens that no single-gene resistances have been found against the potato viruses, and no serious or modern resistance breeding against them has been attempted. This is why we have to endure the incredible expense of planting most potato crops with certified seed tubers. But opposition by crop scientists to the very idea of horizontal resistance has prevented any work on horizontal resistance to potato viruses, and to the various other tuber-borne diseases. Such work could be started at any time.

A similar story can be told about blight resistance. Between 1845 and 1939, blight is estimated to have cost the United Kingdom no less than £5m per annum (i.e., a total £470m in undepreciated currency). The variety *Champion*, which was produced in 1863, had a degree of resistance to blight sufficient to save its crop in Ireland in the bad blight year of 1879, when all others were destroyed. *Skerry Blue* was popular in Ireland for the same reason, even though it had unattractive tubers, and was no greater cropper.

It is clear that the potato experts knew about the quantitatively variable horizontal resistance ever since the first appearance of blight, even if they did not refer to it by that name. They did not often use it because its inheritance was poorly understood and, later, they had fungicides anyway. After World War I, they preferred to work with vertical resistance. Forty years after that, they gave up working with blight resistance completely. And we still spray our potato crops.

The largest monetary inputs in the potato crop, worldwide, are the cost of certified seed tubers, and the cost of spraying with pesticides. The certified seed industry positively *requires* susceptible potato varieties if it is to prosper. And the chemical industry positively *requires* susceptible varieties for the same reason. These commercial influences are not in favour of breeding for horizontal resistance.

Chapter Twelve:

Rubber

When Christopher Columbus made his second voyage to the Western Hemisphere (1493-1496), he saw the people whom he called *Indians* playing a game in Haiti. They were using a ball which bounced, and it was made of rubber. It seems that, in the wealth of new things in the New World, no one had any time for this curious but apparently useless substance.

Later, the Spanish soldier-explorer, Francisco de Orelana, became the first European to explore the River Amazon, by sailing down it from the west, in 1541-42, and he encountered what he thought was a tribe of female warriors. He associated these warriors with the Amazons, the fighting women that the ancient Greeks believed to live on the shores of the Black Sea, and this is how the river got its singularly inappropriate name. But, if Orelana observed the trees which were the source of natural rubber, and which grow wild in the Amazon basin, he did not record the fact.

The second historical mention of rubber occurred more than a century after the first, in 1615, when Spanish records mention various Indian uses for rubber. The Indians used it to water-proof their cloaks by brushing fresh latex on them, and to make crude shoes and bottles by allowing latex to dry over earthen moulds.

The first serious description of rubber was by a Frenchman in 1735. He called it *caoutchouc* (from the Carib word *cahuchu*) and he heard that it was the condensed juice of the *Hevea* tree. In fact, rubber in one form or another is produced by many species of plant and *Hevea* rubber is now known as Pará rubber, named after the

Brazilian State of Pará. This name is pronounced with long a's, and should not to be confused with the Greek prefix *para-* which means “akin to”, or “associated with”, (as in para-medic, para-military), and is pronounced with short a's.

The association of rubber with this Amazonian tree was first confirmed by the Portuguese missionary, Frei Manuel da Esperenca, when he saw the Cambeda Indians using rubber. However, European interest in this substance was minimal. The tree itself was not properly described until 1775, nearly three centuries after the first discovery of rubber by Columbus.

The basic problem was that no one knew how to process the stuff and, until a means of shaping it had been discovered, it was impossible to devise uses for it. The English chemist Priestly discovered accidentally, in 1770, that it would rub out pencil marks on paper. For this reason, the substance was called ‘rubber’ in English and, in the early days, it was known as ‘India rubber’, named after Columbus' false India in the West.

Gradually other uses for rubber were discovered. In 1763, French chemists had discovered that it could be dissolved in turpentine. Later, rectified petroleum and ether were shown to be better solvents, and rubber tubing was first made in 1791. A breakthrough came in Britain, in 1823, when Charles Mackintosh discovered that coal tar naphtha, derived from a coal gas plant, made a good solvent of rubber. Mackintosh coated one side of wool cloth with a solution of rubber, and then immediately laid a second layer of cloth on top of it. This sandwich of wool and rubber produced the first waterproof cloth, and coats made from it were known as mackintoshes.

Mackintosh ran into considerable difficulties because the rubber tended to be hard in winter and sticky in summer, and the seams of the rain coats always leaked because the tailors' needles punctured the rubber. But these difficulties were

eventually solved with another breakthrough which apparently occurred simultaneously in both the United States and Britain.

Vulcanisation

Nathaniel Hayward worked in a rubber factory in Roxbury, Mass., and had discovered that rubber dusted with sulphur was no longer sticky. He became a partner of Charles Goodyear (1800-1860) who accidentally dropped a piece of this sulphur-rubber on a hot stove where it promptly melted. In this way, Goodyear discovered a process which he called vulcanisation, after Vulcan, the ancient Roman god of fire. Vulcanisation involved melting a mixture of rubber and sulphur, and it transpired that rubber could then be moulded into any shape that might be required.

In 1820, in England, Hancock had begun the manufacture of rubber goods made from masticated rubber, and he later extended his operations to France. It seems that Hancock may also have discovered the process of vulcanisation, although the truth of this remains in doubt. Goodyear took out a United States patent for his vulcanisation process in 1844, but it was contested, and he had many legal battles before his rights to it were established. In 1851, he exhibited articles made from vulcanised rubber at the Great Exhibition in London.

However, Goodyear failed to establish patent rights in England or France, possibly because of prior claims by Hancock. Goodyear's attempts to establish factories in both these countries were commercial failures, and his patents were repeatedly infringed in the United States. Although great fortunes were made from his discovery, he himself failed in his various attempts to exploit it and, in 1860, he died a disappointed man, with debts of $200,000, which was a very large sum in the money of those days.

Vulcanisation did several things to raw rubber. It reduced its tackiness, its sensitivity to heat and cold, and its plasticity. Most important of all, it permitted raw rubber to be easily melted and moulded. It also increased its durability and strength. As with alloys of different metals, the proportions of raw rubber and sulphur could be varied. With a low sulphur content, the rubber was soft, pliable, and very elastic. With a high sulphur content, the rubber became hard and brittle, like black glass, or ebony, and it was then known as vulcanite, or ebonite. This substance was an excellent electrical insulator and, before the days of plastics, was used extensively in the manufacture of radios and other electrical goods. A sheet of vulcanite was usually used as the base-board, to hold all the electrical components of an old fashioned, pre-transistor radio.

Once rubber could be vulcanised, with many different degrees of hardness and elasticity, and reinforced with various kinds of fibre, an immense range of new products became possible. One of these was a more durable flexible tubing, called hose after the medieval term for a leg covering. Another was a wide range of belts for transmitting power from one pulley wheel to another, as with car fan belts. Rubber made excellent soles for shoes, and water-proof boots became known as gum boots, because rubber was often compared with other bark exudates, called gums. Another product was foam rubber used in making mattresses, and all kinds of cushions and shock absorbers. It has been estimated that about 50,000 different articles are now made from vulcanised rubber. However, there was one quite special invention which transformed the world. Enter Mr Dunlop.

Wheels

Born in Scotland in 1840, John Boyd Dunlop was the inventor of the pneumatic rubber tire. Until that time there were only two kinds of wheel for

vehicles. The traditional wheel was made of timber and, usually, it had an iron tire both to protect its tread, and to hold the wheel together. These wheels were used on every kind of cart, and horse drawn vehicle, and they were very noisy. In those days, streets were paved with cobble stones, and the horses were shod with iron horseshoes. The noise pollution in a crowded street must have been far worse than anything we have to endure today. It was so bad that, when someone was ill, straw would be laid in the street, so that the invalid could have some peace and quiet.

This was the only kind of vehicular wheel for many centuries. The second kind of wheel was more recent, and was the special, all-metal wheel which dates from the late eighteenth century, when the railway, or railroad, was first developed. Initially, the motive power was the horse but, with the invention of the steam engine, and the steam locomotive, railways transformed land transport. They depend on the fact that a steel wheel rolling on a steel rail has the least friction of all, when moving heavy objects around. Railways rapidly replaced canals and coastal shipping for the movement of goods, and stage coaches for the movement of people.

The development of rubber wheels transformed this situation. One of the earliest uses of vulcanised rubber was to cover the steel tires on wooden carriage wheels. These were the first solid rubber tires and, although a great improvement, they were still very hard. To this day, the coronation coach in England has these rubber tires.

The first motor cars also had wooden wheels with solid rubber tires on them. As can be imagined, these wheels were far too fragile for such a vehicle, and they used to fall apart with monotonous regularity. In those days, the function of a spare wheel was to replace the wheel, not the tire.

John Dunlop was a veterinary surgeon in Belfast and, in 1887, he constructed a pneumatic tire for his son's tricycle. He patented this idea in 1888 and began

manufacturing tires in Belfast in 1890. Initially, Dunlop manufactured tires for bicycles and tricycles and, as a consequence, cycling became an immensely popular, and fashionable, new activity, both for recreation, and as a means of transport.

It was only later that pneumatic tires were used for automobiles, and it was this development, combined with Daimler's invention of the internal combustion engine in 1885, that really transformed the world. About 70% of total rubber production is now used for tires and other components in the automotive industry. Later developments included the huge pneumatic tires used on agricultural tractors, heavy earth moving equipment, and large aircraft.

There were two quite extraordinary incidents in the history of the pneumatic tire. The first was that, after tire production had started in his factory, Dunlop discovered that a pneumatic wheel had been independently invented, and patented, but never exploited, by a Frenchman, nearly fifty years previously. This made Dunlop's own patent void but, by then, he had a number of other patents which protected his invention.

The second extraordinary incident was the way in which rubber cultivation developed almost exclusively in Malaysia, with relatively minor areas of production in Indonesia, Sri Lanka and West Africa. In effect, the entire motor industry of the world became dependent on the rubber production of *one* tropical country. And, during World War II, in 1942, this country was conquered by the Japanese.

World War II

This was the year in which the real manufacturing potential of the United States first became fully apparent. Had Hitler and the Japanese commanders not under-estimated this potential so completely, World War II might never have happened. At the start of the war, the only countries with synthetic rubber factories

were Germany and the Soviet Union, and these factories were quite small. When the Allies lost Malaysia, and the main source of natural rubber, the United States developed a synthetic rubber industry within a matter of weeks, and was soon manufacturing nearly a million tons annually.

The same potential for manufacture in the United States showed with tanks, aircraft, guns, and all the other appurtenances of war, not to mention the potential for research into such things as atomic bombs. Had the Germans and Japanese been better informed, they would have known that they could not possibly compete with America's production capacity, and that, in the long run, and even jointly, they could not win a war against the United States.

Once the war was over, the rubber industry was transformed. The production of natural rubber resumed quite quickly, but the competition from synthetic rubber had come to stay and, with yet another industrial development, there was even more threatening competition from that group of new synthetic substances called plastics.

In the early 1960s, the production of synthetic rubber overtook the production of natural rubber and its lead has been increasing ever since. However, this does not mean that the production of natural rubber is declining. It too has been increasing, in spite of competition from both synthetic rubber and plastics, and it is now at an all time high, even if its rate of increase has been less than that of synthetic rubber.

Natural rubber has certain advantages which synthetic rubber cannot equal. For example, natural rubber is far better at withstanding heat, and tires that develop a lot of heat in a very short period, as with racing cars, and large aircraft, contain a high proportion of natural rubber. Natural rubber also has a superior elasticity, and it can be used to make thinner films. For this reason, it is valuable for making such articles as toy balloons, surgical gloves, and contraceptives.

Plantation Rubber

The first natural rubber was produced from wild trees growing in the Amazon basin. In much of this tropical rain forest, wild rubber trees grow with a natural density of about twenty trees per hectare (eight trees per acre). The first rubber boom was a minor one and resulted from the American Civil War, and the sudden demand for waterproof clothing. In 1890, the world demand for rubber began to explode because of the pneumatic tire, the bicycle, and the automobile. Throughout the Amazon valley, a huge rubber boom began, and great fortunes were made during a period of thirty years.

Manaus, at the confluence of the Rio Negro and the Rio Amazonas, became a boom town. In 1896, they built an opera house there, the *Teatro Amazonas*, in which Enrico Caruso once sang. (Once the boom was over, the opera house fell into disuse and disrepair, but it has recently been beautifully restored by the Brazilian government).

A major port was built at Manaus, with floating wharves to accommodate the seasonal fifty-foot rise and fall in the level of this huge river, which contains one fifth of the world's fresh water. Ocean-going ships still call at Manaus from the Atlantic, some 900 miles downstream. The river traffic extended all the way to Peru, where the town of Iquitos, 640 miles north of Lima, and on the upper reaches of the Amazon, 2,300 miles from the river mouth, became both a boom town and Peru's Atlantic port.

The natural distribution of the Pará rubber tree, *Hevea brasiliensis*, is apparently limited to areas south of the Rio Amazonas, except for a small area west of Manaus. But other, less productive species of *Hevea* were also exploited. It seemed as if everyone living in the Amazon basin set out to harvest rubber. The wild rubber trees produce rubber when the bark is cut. The actual rubber is exuded as an emulsion

in water and it flows as a white fluid called latex. The rubber tappers, called *seringueiros*, hacked the trees with small axes, often spoiling them for further use.

The function of this latex in the tree is as a protection against bark-boring insects, and as a sealant when the bark is mechanically damaged. Any insect larva, which has the temerity to burrow into the bark of a rubber tree, finds itself imprisoned in this sticky latex, which blocks its respiratory pores, and eventually hardens into an immovable casing. Many plant species produce latex for this reason, but *Hevea brasiliensis* is the only one that does so in commercially viable quantities. (One latex producing tree, *Manilkara zapota*, is the sapodilla, or chicle tree, and its latex was the original chewing gum).

Pine trees have a similar defense mechanism except that their imprisoning fluid is not latex but resin, from which turpentine, the favourite solvent of artists, is produced. When the turpentine has been distilled out, the residue is called rosin, and it is used for making sealing wax, and various varnishes and adhesives. It is also used for conditioning violin bows, and every violinist carries a chunk of rosin in his violin case.

Natural rosin can become fossilised, and it is then known as amber. In spite of competition from modern plastics, amber is still worth its weight in gold, because its beauty is unchallenged for lapidary purposes. Amber sometimes contains imprisoned insects, also fossilised, and millions of years old. There is no uncertainty about this defense mechanism which imprisons any insect rash enough to attack the bark. The prison is for ever.

In Brazil, the rubber was collected from the wild trees by people who had little interest in protecting or preserving those trees. The collectors wanted as much latex as possible. And they wanted it on that very day, and the future of the tree was often irrelevant. It is probable that wild rubber trees were fatally exploited, and that they

were tapped so crudely, and so ruthlessly, that many of them died. This was one of the reasons for the collapse of the Amazonian rubber boom in 1920. But another, and far more important, reason was competition from plantation rubber in Malaysia.

As early as 1824, Hancock was the first to suggest that the supply of wild rubber was likely to become inadequate, and that rubber should be cultivated in plantations. He was ignored. It was not until 1870 that Sir Clements Markham, who had collected quinine plants (Chapter 21) in South America, for plantations in Asia, suggested doing the same with rubber. The first attempt was made by a Mr. Farris who collected wild seeds in Brazil in 1873, and sent them to Sir Joseph Hooker, the Director of the Royal Botanic Gardens at Kew. Twelve plants were raised and sent to Calcutta, but they died when planted at Sikkim. A second consignment of seeds, sent from Brazil, failed to germinate.

Henry Wickham then collected some 70,000 seeds from the area between the Tapajoz and Madeira rivers, being paid ten pounds sterling for every hundred seeds. He received a total of £7000, which was a lot of money in the currency of that time. This area has the best natural rubber, and Wickham's choice of it was an extraordinary stroke of good fortune. The entire genetic stock of rubber in Asia is derived from this material, and its quality has rarely been equalled.

Wickham was not a botanist, and he could not even recognise *Hevea brasiliensis*. Indeed, it is doubtful if he even knew that this was the best species to cultivate, or that the area he chose produced the highest yielding trees of this species. He almost certainly relied on native knowledge, because virtually any other area of the Amazon basin would have produced inferior trees.

Wickham was also lucky in that he found a ship, the *S.S. Amazonas*, that was immediately available. This was essential because rubber seeds have a very short life span, and they die within a few weeks of ripening. Wickham’s seeds arrived at

Liverpool and were taken by special train to Kew, on 14th June 1876. They were planted immediately but, even so, only 2,800 of the 70,000 germinated. About 2000 of these seedlings were sent to Sri Lanka in glass boxes, which were a kind of miniature greenhouse, like a terrarium, called ‘Wardian cases’, and which had been devised by Dr. N.B. Ward (1791-1868). The few survivors were planted at Hernaratgoda. These plants began fruiting in 1881 and, in 1888, produced 20,000 seeds.

However, the man who did most to domesticate rubber was H.N. Ridley, the first scientific director of the Singapore Botanic Gardens. He found nine trees from Wickham's original collection when he arrived in 1888. Under his supervision, the Singapore Botanic Garden became a major source of seed, and over seven million seeds, as well as many seedlings, were distributed from these gardens. Ridley also did all the original research on the best method of tapping and coagulating the latex, and propagating and cultivating the trees.

At first, Ridley was ignored. Coffee was the principle crop of Malaysia at that time, and the coffee planters scorned Ridley's belief in the future of rubber cultivation. They called him “Mad Ridley”. As the Disciple Matthew said (XIII, 57), “A prophet is not without honour, save in his own home, and his own country”. In fact, the first rubber plantation was started by a Chinese farmer, Tan Chay Yan, in 1898. But Ridley was soon vindicated. He had been responsible for making propagating material widely available, and more and more planters began to cultivate rubber.

In 1910, there was a rubber boom, with soaring world prices, and large fortunes were made. Ridley was then acknowledged as the “father” of the Asian rubber industry, and he lived many years to enjoy his success. He died in 1956 at the

ripe old age of 101, knowing that his work had produced one of the most recent domestications of a wild plant.

It used to be thought that rubber cultivation was possible within only ten degrees of the equator, and that it required a tropical rain forest climate. This means that it must have at least 100 inches of rain that is evenly distributed throughout the year. Many people think of the tropics being nothing but jungle, a form of vegetation freely associated with words such as dank, dark, dripping, and dense. In fact, most of the tropics are too dry for this kind of vegetation, and are more likely to be thorn scrub and open grasslands. For this reason, there are very few countries that can cultivate rubber.

However, scientists in the Peoples' Republic of China have recently done some remarkable research with rubber trees. They have selected clones which yield well as far North as twenty five degrees, which is actually north of the tropic of Cancer. China has territories which extend well into the tropics, and it now produces 200,000 tons of natural rubber a year, which is half its annual requirement. Rubber is also being cultivated successfully eighteen degrees north of the equator, in Mexico.

Plantation rubber trees are tapped with great care and, as a result, they produce latex copiously for up to thirty years. The tapping is done by making a one-millimetre cut, at an angle of thirty degrees from the horizontal, round half the circumference of the tree. Alternatively, there may be two cuts, each involving one quarter of the tree circumference, and meeting in a "V".

The latex runs down the cut into a small metal spout pinned to the bark, and then it drips into a cup tied to the tree. Unfortunately, the latex coagulates and this prevents further running. So a new cut must be made each day, just below the previous one. This develops a ‘panel’ on the trunk and, after a time, the tree must be

rested to allow new bark to grow. When tapping begins again, it is on the other side of the tree which was left untapped during the previous harvest.

This daily tapping is labour-intensive, and it causes considerable physiologic stress in the tree. Recently, scientists in Malaysia discovered that coagulation could be delayed with a compound called “Ethrel”. Latex flow then continues for 10-15 days with very considerable savings in labour, and an important reduction in tree damage.

The latex is taken to a factory where it is coagulated with either acetic acid or formic acid. The rubber and water are left to separate in special tanks and the rubber is then rolled and macerated so that it can be thoroughly washed and dried. The sheets of rubber may be hung over a fire to dry, and this process produces smoked rubber. In an alternative process, the latex is concentrated with a centrifuge similar to a dairy cream separator, and is exported as a thick liquid. There are various commercial grades of rubber depending on its purity and colour.

Rubber yields have been increasing steadily in Malaysia. When plantation rubber was first started, the rubber yield was about 300 pounds per acre per year. There was no way in which latex collecting from wild rubber trees in Brazil could compete with this. Since then, the yields on the best plantations in Malaysia have been increased more than tenfold, as a result of research and good management, and the wild rubber of Brazil is even more economically forlorn.

Many modern Brazilians believe that rubber was stolen from their country by the British, and that this was the reason for the failure of their own rubber boom. However, Wickham collected his seed with the full knowledge and co-operation of the Brazilian government. No one at that time anticipated the rubber boom which was not to come for another twenty years. Nor was there good reason for anyone to object

to the collecting of seeds of a wild plant, even if there was commercial exploitation of it in progress.

This transfer of rubber from Brazil to the Old World was the equivalent of the much earlier transfer of coffee to the New World, in which Brazil was the principle benefactor. When rubber was taken to Asia, its pests and diseases were left behind, just as the coffee pests and diseases had been left behind in the Old World (Chapter 5). And just as the freedom from pests and diseases gave the New World coffee producers an overwhelming commercial advantage, so the freedom from pests and diseases gave a comparable advantage to the Old World producers of rubber.

South American Leaf Blight

The reason for these differences became apparent when various attempts to establish rubber plantations in Brazil failed. The biggest failure occurred when Henry Ford, of Model T fame, decided to produce his own rubber, in his own plantation, in Brazil. The Ford Motor Company established its first plantation near Boim on the Tapajoz river in 1928, and called it Fordlandia. This was the area in which Wickham had collected the wild seed that became the basis of the Asian rubber industry.

The Ford people planted both locally collected seed, and high yielding selections from Asia. But the plantation failed because so many of the trees died. In 1934, Ford established a second plantation at Belterra, also on the Rio Tapajoz, but this too failed. So did smaller plantations in other parts of the Amazon basin.

Plantation rubber failed in Brazil mainly because of a disease called South American Leaf Blight, known by its acronym SALB, and caused by a microscopic fungus called *Microcyclus ulei*. In the wild rain forest, with its great mixture of many different tree species, every rubber tree is separated from every other rubber tree by yards of dense foliage, which is an excellent filter of microscopic, wind-borne,

fungus spores. But in a plantation, every rubber tree is touching other rubber trees, and the spore density is extremely high. The natural resistance of the rubber tree is not adequate for that density of spores, and the trees die from excessive disease caused by over-crowding.

In 1937, the Ford Motor Company initiated a program of double grafting, in an attempt to solve the SALB problem in a different way. High yielding trunks are grafted on to disease-resistant rootstocks. Because these high-yielding trunks are also very susceptible to SALB, they are crown-grafted as well, so as to carry resistant leaves. After World War II, the Ford Motor Company handed these plantations over to the Brazilian government and their scientists have continued the research. As a result, it is at long last possible to cultivate rubber in its home country.

Population Control

As we saw in Chapter 1, three brutal laws of nature state, first, that there is an absolute limit to the carrying capacity of the environment, second, that there is an absolute limit to the size of that environment and, third, that every species reproduces in excess of the carrying capacity of that environment. The fundamental difference between civilisation and "nature raw in tooth and claw" is that people have used their intelligence to overcome the first two of these brutal laws. Initally, some two million years ago, they did this by increasing the carrying capacity of their environment. Later, about one million years ago, they began enlarging the total environment available to them by migrating into less hospitable, but habitable, environments. By about 10,000 years ago, there was no habitable land left. Our ancestors than made dramatic increases in the carrying capacity of the environment by inventing agriculture. We are now approaching the limits of agriculture, and it is doubtful if we

can achieve further significant increases. And, in spite of this, we are still reproducing in excess of the carrying capacity of our environment.

Very recently, in terms of our total cultural history, the science of medicine has come into its own, after centuries, indeed millennia, of ignorance and superstition. Discoveries such as the infectious nature of disease, immunisation, hygiene, aseptic surgery, anesthetics, antibiotics, blood transfusions, and tissue transplants, have reduced the human death rate dramatically. Unfortunately, there has not been a corresponding decline in the human birth rate. As a consequence, the total human population has been doubling repeatedly, and we are now approaching an over-population disaster.

The time has clearly come when the human species must practice population control. All of our worst global problems, whether of urban sprawl, pollution, garbage disposal, total food production, the world shortage of timber, fossil fuel depletion, or world wars, stem from over-population. If we do not stop our population growth, these problems are going to get worse, indeed much worse, rather rapidly.

As a matter of cold fact, we should not only stop our population growth. We should reduce our total population size by limiting everyone to one-child families, and we should do this for several generations. Once our total population was a reasonable size, we could return to the statistical 2.1 children per family that will maintain a constant population. Given good government, everyone could then live in peace and plenty. Then, *and only then*, the human species would have finally conquered those three brutal laws of nature. And it would be then, *and only then*, that we would have the opportunity to become truly civilised.

Which brings us back to rubber. Natural rubber is the only known substance that is suitable for making important contraceptive devices, particularly the condom. Other contraceptive methods exists, particularly the pill. And new, improved methods

can be expected in the future. But the condom is also the only known method of preventing the spread of AIDS, other than a complete sexual abstinence. This is a very new situation. Until medical research finds alternative methods of preventing the spread of AIDS, and a means of curing the disease when it occurs, the demand for condoms, and for natural rubber, is going to increase exponentially. The total requirement, whether privately purchased or government donated, might eventually be as high as one billion condoms every day. Which is quite a lot of rubber.

Chapter Thirteen

Tea

The British East India Company, which was incorporated by Royal Charter in 1600, was established to win a share in the East Indian spice trade which, by that time, had fallen to the maritime powers of Europe, and was largely controlled by Holland and Portugal. The British navy, under its famous admiral, Francis Drake, had defeated the Spanish Armada in 1588. This radically altered the balance of sea power, and Britain began its slow emergence as the most powerful maritime nation.

The British East India Company was a commercial company, controlled by shareholders in London. But, in spite of this, it became the instrument of British foreign policy in the Far East. It grew into a major political force, and it even had its own army. It met with opposition from the Dutch, and the Portuguese, who had far earlier claims to territories in the Far East, but the British Government was quite prepared to go to war on the Company's behalf.

To be fair, when judging our ancestors, we should judge them according to the standards of their own day. It would not be just to criticise Alexander the Great, for example, for using war as an instrument of policy, when the morality of war was not questioned by Greek philosophers until four hundred years after his death.

Similarly, the Elizabethans, who considered piracy a useful and profitable enterprise, lived some two centuries before the morality of exploiting conquered peoples was questioned by humanists, and at least one century before the morality of

slavery was questioned by sincere Christians. For the Elizabethans, piracy, conquest, and exploitation were quite the quickest, and the most exciting, way of getting rich.

The Dutch had their own East India Company which was similar to the British company. By the standards of today, both the Dutch and the British companies behaved abominably. But, by their own standards, which were fully accepted at that time, their activities were meritorious. In a series of wars in Southeast Asia, the British gradually acquired all the Dutch colonies, except for the islands of the Dutch East Indies, and all the Portuguese colonies, except for Goa and East Timor. They gradually acquired most of India, Sri Lanka, Burma, Malaysia, New Zealand, and Australia, and, for good measure, much of Africa and North America as well.

The main trade of the British East India Company was cotton (Chapter 16) from India. This was the inferior Old World cotton, because the superior Upland cotton from the United States was not yet being produced. Major items of trade also included silk from China, spices, and saltpetre, which was in demand for the manufacture of gunpowder.

From the mid-eighteenth century onwards, tea became increasingly important. At that time, tea was available only from China and, eventually, both the silk and the tea were financed by opium exports (Chapter 21). Very conveniently, Parliament gave the British East India Company a monopoly of opium production in India, and a monopoly of trade with China.

This commercial company ruled India according to shareholders' votes which could be bought and sold. It was undemocratic and exploitive. It was also bureaucratic and inefficient, to the point of near-bankruptcy. Eventually, the British Government interfered, and the Company's commercial monopoly was ended in 1813. It was then that tea plantations began to be established in India. From 1834, the Company became a mere managing agency for the British Government, but even this

stopped after the Indian Mutiny (1857), and the Company was finally dissolved in 1873.

Clipper ships

Unlike the Chinese opium trade, which was an unusually sordid one, the Chinese tea trade was an unusually romantic one. Tea production in China is seasonal, and the first shipments to arrive in Europe, or the United States, fetched the highest prices in a scarcity market. This was before the days of telegraph and radio, and before the days of steamships. The buyers of the first consignments of tea had no idea how much more tea might, or might not, be on its way. This was speculation at its most exciting.

The competition between the ships was so acute that it led to the design of the fastest cargo sailing ships that had ever been built. They were called clippers, and they had forward-raking bows and aft-raking masts. The Chinese tea trade became known as the clipper trade. Clippers were first designed and constructed in the United States, and were later copied in Europe. Perhaps the best, and the most beautiful, was a Scottish one, called the *Cutty Sark*, launched in 1869, and now preserved in a dry dock at Greenwich, on the south bank of the Thames, near London.

China tea

The tea plant is closely related to the ornamental camellia and some taxonomists call it *Camellia sinensis*. Others, however, prefer to put it in a genus of its own, and they call it *Thea sinensis*. The name *sinensis* means "of China" and tea is a truly Chinese discovery, dating from the time of the Emperor Shen Nung, nearly five thousand years ago. The word 'tea' is a corruption of the Chinese ideogram that

is pronounced *tay* in the Amoy dialect. It was also pronounced this way in England until the eighteenth century.

The Chinese usually drink green tea, and they infuse it by placing dried, green, tea leaves in the cup, and then pouring in hot water. The tea is drunk without any of the additives used in the West, such as milk or sugar. The same tea leaves are used repeatedly by the addition of more hot water, and it is considered that the second infusion is the best.

Because Muslim countries controlled the trade between the Far East and Europe, the Arabs became tea drinkers long before tea was known in Europe. The traditional Arab tea infusion is flavoured with rancid ghee. Ghee is clarified butter, and it was common in Arab cuisine because clarification is the only way in which butter can be preserved in warm countries when there is no refrigeration. Rancid ghee is not to everyone's taste, but the Arabs do have other recipes for tea. A Moroccan recipe, for example, with sugar, mint, orange blossoms, and pine nuts, is delicious.

Tea became known in Europe only after the Arab monopoly in trade with the Far East was broken by Portuguese penetration of the Indian Ocean (Chapter 11). Even so, nearly a century passed before tea became anything more than an expensive luxury. In those early days, tea used to cost as much as $400-500 a pound (in present-day dollars) and it would be kept in a special tin-lined box, secured with a lock and key. The habit of tea drinking consequently did not flourish in either England, or her American colonies, until the price came down in the eighteenth century.

Teaspoons

The British custom of afternoon tea was initiated by the Duchess of Bedford in 1840. This new habit quickly became fashionable, and it spread rapidly. Special spoons were designed for this social practice, and they were called teaspoons. It was

at this time also that teashops became popular, particularly in continental Europe. They were also pastry shops (Chapter 6), and they were famous for their delicacies. Iced tea was first produced by Richard Blenchynden, in the St Louis World's Fair of 1904, when it was impossible to sell the hot beverage because of the warm weather. There are now many recipes for iced tea, often employing pineapple, and other tropical fruits.

Assam tea

Tea production in China was a peasant industry, and the first plantation tea was produced in India only in the 19th century, with the ending of the East India Company's tea monopoly. In those days, China tea was considered the only tea fit to drink, and Assam tea was considered unfit for cultivation. The first plantations, at Darjeeling, in Assam, were accordingly planted with China tea. However, the China type did not thrive in Assam.

The China type, *Camellia sinensis*, has small leaves and the cup characteristics of China tea. The Assam type is *Camellia assamica*, and it has large leaves, and the very different cup characteristics of Indian and Ceylon tea. At that time, the Assam type was thought to be a wild tea, but it is unlikely that any truly wild tea has survived the ancient domestication. It is probable that every tea bush in the world has either been planted by people, or is an escape from cultivation. The truly wild plants were probably exploited to extinction.

It has been suggested that the centre of origin of tea is near the source of the Irrawaddy River in Northern Burma, or possibly even further North in the lower Tibetan mountains. It is thought that each type of tea represents the limits of variation that occurred along the two main dispersal routes away from this centre of origin. This dispersal created a *cline* (Chapter 15), with continuous variation between the

extreme of the China type in the east, and the other extreme of the Indian type in the west. There is also a third Cambodian type in the south, but it is of minor economic importance.

When the British decided to grow tea in Assam, in India, they decided to import the China type. This was the first time that the two extremes of the cline had been brought into breeding contact. There was immediate hybridisation and, as a result, cultivated tea in India became a hybrid swarm with every degree of hybridisation between the two types. This has produced enormous variation within the Indian tea crop.

When the British discovered that the China type grew only poorly in Assam, they had to abandon it in favour of the so-called wild type, or Assam tea, which grew far better, and yielded much more, than China tea, even if its cup quality was inferior. All subsequent tea development in India and Sri Lanka (then called Ceylon) made use of the Assam type. Tea drinkers in the West are now so familiar with the Assam type that they regard it as the best. Tea connoisseurs, on the other hand, prefer the teas of China, and they disdain Assam tea, in much the same way that wine connoisseurs disdain beer.

We must recognise, however, that the China teas introduced to Darjeeling by the British left an ineradicable mark. The inter-breeding between the two types of tea means that most of the present-day Assam tea has been improved by at least some genetic mixing with the China type. To this day, Darjeeling produces the best of the Indian teas, and this may well be due to the high proportion of China tea in its pedigree. It was the poor quality of Assam tea that first led to the blending of teas, so that the quality of cheap, bulk tea could be improved by the addition of superior types. Today, most commercial teas are blends, and only the speciality teas are pure.

Clonal tea

The genetic variation within plantation tea is now so wide that it is almost impossible to produce an improved variety by propagation from true seed, even when the seed is produced from selected clones in special seed gardens. This is because the seed is heterozygous (Chapter 2), and it does not ‘breed true to type’. Consequently, there is immense variation within a crop grown from true seed.

Traditionally, tea was always planted from true seed, and this kind of crop, known as ‘seedling tea’ to distinguish it from vegetatively propagated clonal tea, was so variable that more than half of the yield would often come from less than a third of the bushes. The first real improvement in plantation tea came from the use of clones, in which all the plants are identical, because they have been propagated vegetatively, by cuttings, from one original parent. If that original parent was a carefully selected, high yielding, high quality individual, the entire crop, consisting of its clone, would have equally high yields and quality.

Tea clones are produced by selecting promising bushes within a seedling tea crop. As with all plant selection work, the easiest tests are conducted first, when there are many plants to test, and the most difficult and laborious tests are conducted last, when there are only a few plants to test. It is estimated that about one million seedling tea bushes must be screened in order to obtain one really good clone.

The first test is a simple visual assessment, made by skilled people walking through the crop, and about one bush in a thousand is marked as being promising. More detailed, and more difficult, subsequent tests are for yield, cup quality, rooting ability, and resistance to pests and diseases.

The tea industry is a remarkably conservative one and, for many years, there was considerable resistance to the suggestion of abandoning seedlings in favour of clones. After thirty years of breeding work, designed to produce improved seed by

crossing selected clones, the best seedling progenies were producing fifty percent more than unimproved seedling tea. But the best clones yield twice as much again, and their cup quality is immeasurably superior.

In the old days, it was believed that tea cuttings would never form roots. This was because the rooting techniques were primitive. The cuttings were put into a rooting medium that was rich in plant nutrients, and rich in organic matter and microbiological activity. The leaves were trimmed to reduce water loss, and the cuttings were heavily shaded. They usually died, or rotted, long before roots could form.

Modern horticulturists never treat cuttings in this way. They retain all the leaf on the cuttings, and expose them to a high light intensity. This encourages the maximum rate of growth. Water loss is prevented by keeping the leaves wet, in a mist propagator. And the rooting medium is both nutritionally and biologically inert. Under these conditions, tea cuttings remain healthy, and they form roots in about ten weeks.

Left on its own, a wild tea bush will grow to a height of several metres. Cultivated tea crops must consequently be pruned to produce a flat top called the 'platform' or the 'plucking table' of young shoots growing at about waist height. It is possible to walk between the bushes, but only by pushing the branches aside, as they all touch each other and the crop appears to be continuous. Tea crops are the greenest of green in colour, and are very beautiful, particularly when seen from a distance, like a vivid green carpet spread over rolling hills.

Tea pickers walk between the bushes in order to pluck the young shoots. The rule is that they pluck the leaf bud and two leaves, because older leaves have an inferior cup quality. The shoots do not develop in unison, and several pluckings are necessary to obtain all the shoots of one harvest. The plucked shoots are tossed into a

basket carried on the back. Most tea pluckers are women and the crop is a labour-intensive one. The pluckers must wear waterproof clothing because rain is frequent in tea growing areas, and the tea bushes are usually wet,

A ‘flush’ of new shoots is produced several weeks after each harvest and, depending on the environment, three or four harvests may be possible each year. After each harvest, the height of the ‘platform’ increases slightly and, eventually, it becomes too high for convenient plucking, and the crop must then be pruned. This happens after five to seven years, depending on the environment and the kind of tea being grown. Assam types require more frequent pruning than China types.

Research in Kenya

Traditionally, tea was grown under shade trees. This practice was defended on the grounds that wild tea was an under-story shrub, and it preferred shade. It was also argued that the shade trees put their roots down much deeper than the tea, and brought nutrients up from the deep subsoil. These nutrients were eventually made available to the tea in the form of leaves shed by the shade trees. Some shade trees were members of the botanical family *Leguminoseae* and, it was argued, these trees fixed atmospheric nitrogen and made it available to the tea, thus saving on nitrogenous fertilisers. It subsequently turned out that these traditional practices were based on no scientific evidence whatever and, in fact, that they were wrong.

In a brilliant experiment in Kenya, plant physiologists dug a pit beside a shade tree and a tea bush. They traced the roots of both trees to see how far down they went. The pit got deeper and deeper until it had to be shored up like a mine shaft. This area has very deep volcanic soils, and the pit still kept getting deeper and deeper, with the roots of both trees still going down. Eventually, when the pit was sixty five feet deep, they could go no deeper. But the roots of both trees had been traced all that way. It

has now been shown that tea yields better without shade trees, provided that it is kept well nourished with fertilisers and irrigation. And the same has also been shown for other tropical tree crops, such as coffee and cocoa.

In another experiment, also conducted in Kenya, scientists discovered why tea never seemed to respond to phosphate fertilisers. Traditionally, tea is kept well weeded, and the weeding is down by hand with, hoes which break up the top soil. And, in tropical soils, phosphates are often locked up chemically, quite quickly after application. This experiment showed that the weeding was destroying the feeder roots of the tea. If the soil was covered with an organic mulch, these feeder roots developed properly, and they would absorb phosphates before they had time to become chemically unavailable. The tea then responded magnificently to applications of phosphate fertiliser, and yields were increased accordingly.

Tea research in Kenya produced yet another highly original experiment. Most tea estates has an occasional patch of dead or dying tea bushes, and the cause appeared to be a common fungus called *Armillaria mellea*. This fungus is sometimes known as the “boot-lace” fungus because it produces black, underground rhizomorphs that look just like boot laces. It was also believed to kill tea bushes and, apparently, there was no way of stopping it from spreading through the soil. My friend Ian Gibson was asked to investigate this problem, and his first task was to measure just how quickly the *Armillaria* was spreading, and killing tea bushes as it went.

He did this in a very ingenious way. The whole of Kenya had been surveyed from the air in order to make maps. And it had been surveyed in this way not once but twice, with an interval of several decades. And the original photographs were still available in the archives. By comparing modern aerial photographs of *Armillaria* patches with those of decades earlier, he was able to show that these patches were not

increasing at all. In other words, it was not the *Armillaria* that was killing the tea. The *Armillaria* was merely feeding on moribund tea that was dying of other causes. Each patch was then shown to have very shallow soil, to be subject to water-logging, or to have some other ‘site problem’ that was not an infectious disease.

In the 1920s, it was discovered that the land around the town of Kericho, in Kenya, was excellent tea country. Big tea companies from Britain were invited to establish tea estates, and this added considerably to the wealth of the country. Sadly, all small farmers, who were invariably Africans, were forbidden to grow tea as it was feared that their tea would be inferior, and that it would damage the good name of Kenya tea. Much later, the Tea Research Institute at Kericho produced a wonderful new clone called 6/8. However, the big tea companies could not grow any of the new clone as all their land was fully planted to seedling tea. Clone 6/8 became available at the time of Independence in 1963, when the law forbidding small farmers to grow tea was repealed. Many small farmers planted tea, and it was all clone 6/8 which produced tea of a much higher quality than the seedling tea. And it is the seedling tea of the big companies which now threatens the good name of Kenya tea, because it is the Kenya small-holder tea that now fetches top prices on the London market. This is poetic justice of a rare and transparent quality.

Harvesting and processing

Tea is a labour-intensive crop, and it is expensive for this reason. The mechanisation of tea picking has so far proved impossible, except in Russia, where tea is grown on very flat land. The Russians grow their tea in parallel hedges, and they lay a single railway line between each hedge. A picking machine, which is equipped with hedge trimmers, is mounted on a special rail car which straddles the hedge and, with considerable precision, it trims the hedge of all new shoots, both on

the top and the sides, as its runs along the rails. The trimmings are collected by the machine, and sent to the factory. Mechanical harvesting also occurs in Australia.

The plucked leaf, whether hand or machine harvested, is taken to a tea factory for processing. The leaf is first withered, or wilted, by being partly dried, and it is then macerated in special machines which bruise the leaves. The macerated leaf is then fermented to produce the so-called black tea of commerce. This is not a true fermentation, as micro-organisms are not involved. The changes are due entirely to chemicals released within the leaves by the maceration process, and their reaction with the atmosphere.

With fermentation, the tea becomes a dark copper colour and the typical tea aroma develops. The final process is called ‘firing’, and this involves a fairly rapid drying of the fermented tea in forced hot air. The dried tea is then sifted and sorted, to produce various grades, called ‘fannings’. The best grade with the highest proportion of buds is called orange pekoe. A very special grade consists of buds only, and is called ‘golden pekoe fannings’. Unfortunately, it is too rare, and too expensive, to be on sale to the public.

One of the many variables in seedling tea is the time required for fermentation of the crushed leaf. Some bushes require a much longer fermentation time than others. A harvest taken from seedling tea thus produces a ferment in which some of the tea is over-fermented, while some is under-fermented. It requires great skill on the part of the factory manager to judge the best time to stop the fermentation process. This problem does not occur with clonal tea, because all the leaf ferments at an equal rate, and this is a major factor contributing to the high cup quality of clonal teas.

Many Chinese and Japanese teas are processed without fermentation, and are called green teas. Fermentation is prevented by steaming the leaf before it is dried. A semi-fermented product is called *oolong* tea.

Tea merchants in the importing countries usually blend their teas to maintain a uniform quality, often sold under a popular brand name. The final cup quality is also governed by the nature of the drinking water, and people living in hard water districts need a more robust blend than those in soft water areas.

Traditionally, the tea of commerce was a loose tea referred to as 'tea leaves' and, when the brewing of loose tea was still common, tea bags not having been invented, the arrangement of the tea leaves on the bottom of the cup was a popular method of telling fortunes. Tea bags were invented by Thomas Sullivan, a New York tea merchant who decided to send free samples to his customers in small bags which could be infused without being opened. These proved so convenient, and so popular, that the idea of tea bags caught on very quickly. There is a popular prejudice in Britain which says that only inferior tea is put into tea bags. This may have been true once, but it is no longer correct.

The methods of infusing tea vary quite widely. The general rule is that the best components, such as the more delicate aroma and the stimulants, infuse quickly. The worst components, such as tannins, which contribute colour, and the crude aroma, infuse slowly. China green tea will tolerate long periods of infusion because it contains little tannin, but black Assam teas, which are rich in tannins, will not tolerate prolonged infusion, or repeated infusion. The so-called "stewed" tea, beloved of the British army, dark and strong, and "a regular sergeants' brew", is possibly the worst kind of tea, appreciated only by undiscerning men whose need for refreshment is acute.

Preparation

Like coffee, tea must be drunk when fresh. Infused coffee spoils after about half an hour. Infused tea spoils even more quickly. This is possibly the reason why

tea infusions will not tolerate the dehydration process required to make ‘instant’ tea. Instant coffee is popular, but instant tea has never been a success. However, it must be added that, to a purist, coffee infusions will not stand being dehydrated either, and that instant coffee is a beverage of sorts, but it is not true coffee.

Like coffee also, tea will not tolerate being boiled. Both tea and coffee are ruined the instant they begin to boil. This is because the flavour of both drinks depends on highly volatile aromatic compounds, which are quickly released to the atmosphere, at the temperature of boiling water. Anyone who comes down to breakfast, in a house which is filled with a gorgeous smell of coffee, will probably have dreadful coffee to drink, because it is coffee that has been boiled. This explains why the old-fashioned percolator produced such bad coffee, and the more modern drip and filter systems are now preferred.

These volatile aromatic compounds must also be carefully preserved during storage of both tea and coffee. The best way to store coffee is in the form of roasted beans which, like black pepper and nutmeg (Chapter 10), must be ground immediately before use. The aroma of freshly ground, and freshly brewed, high quality coffee is one of the finest in the world. The best way to store tea is very dry, and in an air-tight container. Tea kept exposed to a damp atmosphere will quickly lose the best components of its aroma. This is less important with the black Assam type teas, which have the least delicate aroma. But it is very important with the green China teas.

Dried tea leaves absorb scents and aromas very easily. If tea is stored in atmospheric contact with soap, for example, it will be ruined. This property of absorbing aromas has been exploited in many speciality brands of scented tea. Jasmine tea, and lemon scented tea, are well known. Other scents include peppermint, mixed spices, blackberry, and Muscat grapes (muscatel). People tend to be strongly

polarised over the tarry, old rope flavour of *Lapsang Souchong*, which is either greatly relished, or greatly disliked.

Earl Grey tea is named after Charles Grey, the second Earl who, as Prime Minister, was responsible for the Parliamentary Reform Act of 1832, which greatly expanded the antiquated franchise known as the ‘rotten boroughs’. He had to call an election to obtain support for his reform Act, and he had to create new peers to get it through the House of Lords. But his Act transformed British politics with greatly improved democracy, and, among other things, led to this tea being named in his honour.

Earl Grey tea is probably the most popular of the scented teas. It is perfumed with bergamot oil. This oil is obtained from the rind of a special variety of Seville orange grown near the city of Bergamo, in Italy. A greatly inferior oil, known as wild bergamot, is obtained from a species of mint, *Mentha citrata*.

Boston tea party

Finally, no account of tea would be complete without a reference to the Boston Tea Party. As every school child knows, the English taxed the tea, the colonists got annoyed, there were cries of "no taxation without representation", the good people of Boston threw British tea into the harbour, the thirteen colonies declared themselves independent, there was a glorious war, and the United States came into existence.

As every historian knows, the details of this simple story were complicated almost beyond belief. There was a heavy burden of taxation in Britain, which the English attributed to the high cost of maintaining an army in the New World colonies. There was disagreement as to whether the home country, or the colonists, should pay these costs. Both sides had a valid case.

The last straw was when Parliament granted various privileges to the British East India Company, which was verging on bankruptcy. These privileges included a refund of import duties already paid on tea in London warehouses, if the tea was re-exported to the Colonies. Most New Englanders drank an inferior Dutch tea, because it was cheap, having been smuggled into the Colonies without taxes. The new privileges of the East India Company made the higher quality English tea cheaper than the Dutch tea. Opposition to the new privileges came mainly from the Boston tea traders, who had grown accustomed to the profits from the illicit Dutch tea trade. Many of them were in a precarious financial state because this was a period of heavy indebtedness, resulting from excessive borrowing, and speculation.

Additional concern arose among the colonists when Parliament, with great enlightenment, granted a new constitution to the previously French colony of Quebec, allowing these people to retain the Roman Catholic religion, French law, and the French language. This convinced the New England Puritans that there was a Catholic plot.

There is no need for us to re-fight these old battles. The 'Boston Tea Party' was really quite unimportant. It was merely the microscopic speck which can permit a crystal to grow. This crystal was independence which, of course, needed no justification at all, other than the simple desire of people to govern themselves.

Chapter Fourteen

Coffee

Because of its historical interest, this chapter has been extracted, and slightly abbreviated, from my earlier book Return to Resistance*. Readers who are familiar with this earlier work may safely skip to the next chapter.*

In spite of the fact that coffee is an old world crop, there are no early historical references to it. There is no mention of coffee in ancient Egyptian, Sumerian, Greek, or Roman records. Nor is coffee mentioned in the Bible or the Koran. It seems that the first historical reference to coffee is an Arabian one, dating from the ninth century AD.

The Swedish taxonomist Carolus Linnaeus (1707-1778) believed coffee to have originated in Arabia and, more specifically, in *Arabia Felix* (Southern Yemen). He accordingly gave it the Latin name *Coffea arabica*. In fact, Linnaeus was mistaken. We now know that coffee originated in Africa, in the eastern, equatorial highlands. *Coffea arabica* was probably an accidental hybrid between two wild species and, somewhat tentatively, we can both date the time of this accident, and locate where it occurred.

Origins

Arabica coffee must have appeared at least a century before its first historical record in 850 AD, and the earliest possible date can be determined by the spice trade of the ancient Romans. In his book *The Spice Trade of the Roman Empire* (1969), J.I. Miller has described how the Romans obtained cinnamon (*Cinnamomum*

zeylanicum). At that time, this spice was being produced only in the general area of lowland, tropical S.E. Asia, and its source was a well kept trade secret.

The Romans believed cinnamon to come from Africa but, in fact, it was taken to Madagascar by ancient Austronesian people, who used to sail from Indonesia, straight across the Indian Ocean, as early as the second millennium before Christ. These people also brought the banana, rice, turmeric, and an Asian species of yam, from Asia to Madagascar. The present day inhabitants of Madagascar, the Malagasy, are descended from them. Their language is not one of the African languages, and it belongs to the Austronesian family of languages. Unlike any other people in Africa, the Malagasy have also cultivated paddy rice, in the Asian manner, since antiquity.

It seems that these Austronesian sailors relied entirely on the monsoon winds to make this 6,500 kilometre journey across open ocean, and that, for this reason, their journeys were strictly seasonal. It is probable also that they relied on the coconut to provide them with both fresh water to drink, and vitamin C to prevent scurvy (Chapter 9). One of their items of trade was the scented bark of the cinnamon tree, and the principal market for this bark was the city of Rome.

From Madagascar, the cinnamon was taken by canoe to the east coast of Africa, to an area near the modern border of Kenya and Tanzania which, in ancient times, was called Rhapta. From there, the trade route went overland. This was possibly because the sea journey round the Horn of Africa, to the Red Sea, was too hazardous. The land caravan would also be greatly enriched in the course of its travels. By the time it reached the Mediterranean, the caravan would have gained wild animals for the Roman circus, Nubian slaves, ebony, ivory, frankincense, gold, and other rare African luxuries.

The overland route went through the area of modern Kenya to southern Ethiopia where it forked. One fork went northwest to the Blue Nile, then by river boat

to Alexandria and then, by sea, to Rome. The other fork went northeast to Assab, on the Red Sea coast, where the remains of an ancient Roman port still exist, and then by sea, with a short overland journey at Suez, to the Mediterranean and Rome.

The point about this trade route is that it went right through the heart of the traditional coffee growing areas of Ethiopia, and yet the Romans never knew about coffee. It is inconceivable that the Roman spice trade, which was so sophisticated that it included Indonesian cinnamon, would have remained unaware of such a stimulating and important beverage as coffee, had it been present in Ethiopia at that time. We must conclude, therefore, that coffee was not present in Ethiopia during the period of the Roman spice caravans. The Roman spice trade collapsed with the fall of Rome, and we can accordingly date the appearance of coffee at not earlier than 450 AD, and not later than its first historical mention in 850 AD. For convenience we can set a tentative date of about 650 AD.

The origins of arabica coffee can be determined from botanical data with a fair degree of confidence. There are some sixty species of wild coffee in Africa and India. These wild species are all diploids. That is, they have two sets of matching chromosomes, with one set coming from the male parent and the other from the female parent. Each set has eleven chromosomes and diploid coffees thus have twenty two chromosomes. (A chromosome is a microscopic bundle of the DNA genetic code that controls all things inherited).

Arabica coffee differs in that it is a tetraploid. That is, it has four sets of chromosomes. It is thought, but not finally confirmed, that this is a new species that arose when a rare hybrid was formed between two different wild diploids. Such a hybrid would normally be sterile, because the two sets of chromosomes would not match each other. However, a spontaneous doubling of the number of chromosomes can sometimes occur, and a sterile hybrid then becomes fully fertile, because it now

has two double sets of chromosomes, and the two doubled sets match each other. It is highly probable that arabica coffee was formed in this way.

An immediate question is where did this accidental hybridization occur? One of the more notable botanical features of Ethiopia is that no wild, diploid coffees occur in that country. We can be confident of this because many botanists, myself included, have searched for them without success. A second question, related to the first, concerns the identity of the wild parents of arabica coffee.

The late and little known scientist, I.R. Doughty, is reputed to have hybridized two wild diploids, *Coffea eugenioides* and *Coffea canephora*, at the Lyamungu Research Station, on the lower slopes of Mount Kilimanjaro, in Tanzania. He did this in the late 1930s, and he obtained a sterile hybrid. However, one lateral branch underwent a spontaneous doubling of its chromosomes, and it became tetraploid and fertile. Apparently this fertile branch was indistinguishable from *Coffea arabica*.

Unfortunately, World war II interrupted his research and, when Doughty returned to Lyamungu after the war, the hybrid tree had disappeared. Unfortunately also, Doughty, who was in many ways a brilliant scientist, disliked writing, and he published little. Doughty died many years ago, and his experimental records are lost. I met him on several occasions but, alas, it never occurred to me to discuss his coffee work. His colleague, who remembered this work, and told me of it, has also died. This evidence is consequently hearsay evidence only, and Doughty's work on identifying the wild progenitors of Arabica coffee must obviously be repeated.

A few of the wild diploid coffees are cultivated, but they all produce coffee that is inferior to arabica, and they all occur wild in Western Africa. This natural distribution would explain why these coffees also remained unknown to the Romans. One of these cultivated diploids is *Coffea canephora* which produces the ‘robusta’ coffee of commerce, and was used by Doughty in his hybridization experiment.

The eastern limits of the natural distribution of this species are in Uganda or, possibly, western Kenya, but well to the west of the cinnamon trade route. Doughty's other species, *Coffea eugenioides*, is an East African species, of no culinary value, that also extends into Uganda. If these two species are indeed the progenitors of arabica coffee, the centre of origin must be in the area where their natural distributions coincide. That is, in the general area of modern Uganda.

The hypothesis, then, is that arabica coffee is a tetraploid species, derived by hybridization between *Coffea eugenioides* and *Coffea canephora*, in Uganda, in about 650 AD. New tetraploids often have characteristics that are considerably different from either of their parent species. Quite frequently, they have different climatic requirements from either parent and, for this reason, they often flourish in a new area, called the centre of diversification, which may be quite distant, and considerably different, from the centre of origin. Apparently, this happened with arabica coffee. Uganda is too warm and moist for arabica coffee, which probably died out there soon after it was formed. In the meanwhile, however, it was taken to Ethiopia, which became its centre of diversification.

Distribution

The relatively cool highlands of Ethiopia are separated from the more lush and humid, tropical environment of Uganda by an arid and forbidding arm of the Sahara Desert, that extends from southern Sudan to the Horn of Africa. We must presume that seed of arabica coffee was taken from Uganda to Ethiopia by travellers, possibly as a gift from one king to another. We have good reason to believe this because, it seems, a disease of the wild coffees was left behind. I shall return to this point in a moment.

Coffee obviously became popular in Ethiopia, and its cultivation spread widely. By the ninth century it had become an important item of trade with the Arabs living across the Red Sea in the Arabian peninsular. It will be remembered that the Prophet had forbidden his followers to drink alcohol, and Muslims consequently had only water, fruit juices, and milk to drink. They also had tea, but it was incredibly expensive, and rare, having been brought all the way from China. Coffee consequently became a very important beverage for them but, after a war had interrupted the supply of Ethiopian coffee, the Arabs decided to produce their own. They started cultivating coffee in the Yemen, in southern Arabia. As we have seen, Linnaeus believed that coffee originated in this area and, following centuries of selection and improvement by Arab farmers, these crops became famous as Mocha coffee, the finest of them all.

During the seventeenth century, coffee became popular in Europe. The first coffee house in London was established in the early part of that century, and coffee houses soon became important meeting places for social, political, literary, and business activities, in both Europe and America. Samuel Pepys mentions coffee houses frequently in his London diary (1660-1669) where they were usually known by the name of the owner. Lloyd's coffee house became famous as an insurance exchange, and Boodle's and White's became famous London clubs. In France, coffee houses became so important that they gave their name, *café*, and its derivative *cafeteria*, to most of the languages of the world.

The Arabian production was inadequate for these rapidly expanding markets of Europe, and coffee became increasingly expensive. In its turn, this stimulated production in other parts of the world. The Arabs were probably the first to take coffee seeds from Arabia to India and Sri Lanka. The Dutch took coffee seed to the island of Java, in modern Indonesia. In 1706, they took one coffee tree from Java to

Amsterdam and, as a gift, sent one of its progeny to the *Jardin des Plantes* in Paris. The French sent seed taken from their single tree to Martinique in the West Indies. Attempts to maintain a French monopoly failed, and the crop was soon being cultivated in various parts of central and south America. Four points about this world distribution of coffee are of interest.

The first concerns the narrowing of the genetic base. Coffee is most unusual, among tree crops, in being self-pollinated. This means that all the seeds coming from one tree tend to be genetically identical. They are homozygous and they 'breed true to type'. Every time coffee was moved from one country to another, transported usually as a single tree, or as only a few seeds taken from one tree, there was an increase in the genetic uniformity, a narrowing of the genetic base. This meant that the coffee that finally reached the New World was a pure line, and all the trees were identical.

This uniformity has considerable agricultural and commercial advantages, but it makes coffee breeding very difficult, because genetic improvement depends on crossing differing types to produce variation. Coffee breeding was impossible in the New World until other coffee lines were introduced, and this happened only to a very limited extent, and only during the present century.

The second point of interest is that, when coffee was moved from one country to another, its pests and diseases tended to be left behind. By the time coffee reached the Americas, it was virtually free of parasites. This freedom from parasites gave the New World an enormous commercial advantage over the Old World, where coffee parasites were common. Until quite recently, the control of coffee parasites was extremely difficult, because modern insecticides and fungicides did not exist. The New World advantage was thus a crucial one, and it led to a commercial domination, in which the Americas now produce about eighty percent of the world's coffee. This happened in spite of the fact that, for about 250 years, the entire coffee crop of Latin

America consisted of only *one* pure line. This degree of monoculture, and genetic uniformity, positively invites ruinous epidemics.

This brings us to the third point, and an even less attractive aspect of this situation. All this coffee in the Americas is free from parasites, but it is also very susceptible to those parasites, should they ever reach the New World. As we have seen (Chapter 5), this situation is called crop vulnerability, which means that the crop is susceptible to an absent, epidemiologically competent species of parasite. When the parasite arrives in the area of cultivation, the susceptibility is revealed, and the vulnerability is manifested. Potential damage then becomes actual damage.

The fourth point of interest arising from the international movement of coffee concerns the resistance of the coffee itself to its pests and diseases. When the new hybrid of arabica coffee was first formed in Uganda, about fourteen centuries ago, it had as much resistance to coffee parasites as its wild progenitors. This natural level of resistance is a very high level, because all wild plants must have adequate levels of resistance to all their parasites. This is axiomatic, because any individual plant, or species of plant, that had poor resistance, would be unable to survive ecological and evolutionary competition, and would have either accumulated enough resistance, or become extinct, long ago.

The role of disease

As we saw earlier, the new coffee hybrid was taken to Ethiopia in about 650 AD, and, apparently, one of its parasites was left behind in Uganda. This was the microscopic fungus *Colletotrichum coffeanum* (pronounced *colley-tot-tree-coom*, and *koff-ee-ay-noom*), which causes a disease called coffee berry disease (see below). The new coffee hybrid was then cultivated in Ethiopia for some fourteen centuries in the absence of this fungus. Plants which grow in the absence of a parasite tend to lose

resistance to it. They become highly susceptible and, possibly, highly vulnerable as well. However, all the other coffee parasites were present in Ethiopia and the coffees of the Ethiopian highlands have remained resistant to all of them.

There is one exception to this rule of resistance in Ethiopia. In eastern Ethiopia, there is a relatively dry province called Harrar. The coffee of Harrar has been grown for centuries in an area where most coffee parasites have a greatly reduced epidemiological competence, due to the dry atmosphere, and the relatively dry soils. The Harrar coffee has consequently lost resistance and, when it is cultivated in wetter environments, such as southwest Ethiopia, it is highly susceptible to many coffee parasites, including coffee berry disease.

The susceptible Harrar coffee was almost certainly the coffee taken in the thirteenth century to the Southern Yemen by the Arabs, where it was grown for several centuries in a climate that is even drier than Harrar. The coffee of this area probably lost even more resistance. This was the coffee that was taken to Indonesia and, later, to Europe, and the New World. There seems to be little doubt that the coffee of the Americas is both a narrow gene base coffee, and is a very susceptible coffee. Indeed, all the arabica coffee of the world, outside of Ethiopia, has suffered a major erosion of horizontal resistance to many of its parasites.

This is a ludicrous situation. If the Dutch had taken coffee from southwest Ethiopia to Java, instead of from Yemen, there would be *no serious pest or disease problems of arabica coffee anywhere in the world,* apart from coffee berry disease (see below). In other words, all the serious parasite problems of arabica coffee are due to an erosion of resistance. Three points about this erosion merit discussion.

First, this comment is not a criticism of those early, and very courageous, Dutch explorers, because there was no way they could have understood this complex situation. Equally, there was no way they could have reached southwest Ethiopia

which, in those days, was a completely inaccessible part of the entirely unknown, and very dangerous area known as darkest Africa. South Yemen was close to the sea and, for all that these Dutch explorers knew, it was the only place in the world where coffee was cultivated, or even existed. As we have seen, Linnaeus believed it was the home of arabica coffee.

Second, this situation indicates just how important an erosion of resistance can be. Eighty percent of the world's coffee production is in the New World because this area is free of so many coffee parasites that were left behind in the Old World. This indicates how serious these parasites really are, because coffee is so much more difficult to produce, and it has such a competitive disadvantage, when it is cultivated in the Old World.

Third, the extent of this erosion indicates the potential of horizontal resistance in a crop such as arabica coffee. Eventually, it should be possible to breed arabica coffee with enough horizontal resistance to permit its cultivation anywhere in the cool tropics, without any crop protection chemicals, and without any loss of either yield or quality. Indeed, such coffee varieties already exist, as we shall see in a moment.

Because the coffee in the New World is so susceptible, it is clearly also vulnerable to many Old World, re-encounter parasites. This is a dangerous situation, but there is one clear advantage. There is obviously tremendous scope for breeders who are working with resistance to coffee pests and diseases, provided that they are willing to work with horizontal resistance.

Coffee berry disease

At the end of the last century, the British started coffee cultivation in Kenya, using susceptible coffee taken from the New World. After World War I, they initiated a large coffee expansion project in western Kenya, near to the Uganda border. For the

first time in about thirteen centuries, arabica coffee came into physical contact with its wild progenitors in its centre of origin, and the inevitable happened. *Colletotrichum coffeanum* moved into the cultivated coffee, and it caused a devastating disease, now known as coffee berry disease. This disease was new to science, but it was not new to nature. As we have seen, it occurred on the wild coffees all the time, and it had been inadvertently left behind when the new hybrid was taken to Ethiopia, in about 650 AD.

As its name implies, coffee berry disease is a disease of the green, unripe, coffee berries. Although the parasite can survive non-parasitically in the bark of the coffee tree, it can only parasitise the berries, and it does not harm any other part of the tree. The berries, of course, contain the coffee beans, and they are the harvestable product. In a very susceptible tree, all the berries are destroyed by the disease several months before harvest time. Obviously, the disease can be a very damaging one.

As we have seen also, this kind of parasite is a 're-encounter' parasite. The crop was taken by people to another part of the world, and the parasite was left behind. The crop then lost resistance to the parasite. Eventually, when this susceptible crop and the parasite re-encountered each other, the parasitism was very damaging because of the loss of resistance. Coffee berry disease is a typical example of a re-encounter parasite. And it is a very damaging disease. Indeed, the coffee expansion project in western Kenya was a complete failure, and many farmers, who were mostly World War I veterans, were financially ruined.

Coffee berry disease was first described in Kenya by J. MacDonald in 1926 and, observing that some trees were more resistant than others, he recommended the use of resistance as the best means of control. But MacDonald was not believed, mainly because coffee breeding was a long-term project. The work on resistance breeding was stopped, and the research in Kenya turned to fungicidal chemicals.

Ironically, some of MacDonald's best coffee selections, which have useful levels of resistance to coffee berry disease, were used successfully in other parts of Africa, where the disease had a lower epidemiological competence. And, although susceptible, most of the coffee in Kenya is now considerably more resistant than the most susceptible coffees from Harrar.

I met MacDonald, when I first went to Kenya, in 1953, and when he was an old man. Sadly, his percipience concerning resistance to coffee berry disease was recognised only long after his death.

Coffee berry disease soon started to spread inexorably through the cultivated coffees of Africa. In 1970, the disease reached Ethiopia, where coffee provided 60% of the country's exports. It was apparently taken there by people trying to improve Ethiopian coffee production with seed from Kenya. Coffee berry disease is not normally carried in coffee seed, but it seems that this batch of seed was dirty, and it contained many dried remains of diseased fruit tissues. Unfortunately, these foolish people distributed this dirty seed among many friends throughout the country, and the disease erupted all over the coffee areas of southern and western Ethiopia. The disease was soon threatening to destroy up to forty percent of the already low coffee yields.

In those days, coffee in Ethiopia was being cultivated according to centuries-old traditions. It was not planted in neat rows, to permit mechanical cultivation, nor was it manured, or pruned. The crops were a genetic mixture, with most of the trees being different from each other. And the only cultivation involved the weeding of the dense tropical vegetation, once a year, so that the pickers could reach the trees. The average yield was only 10% of the best commercial yields in neighbouring Kenya. Under these circumstances, coffee berry disease was ruinous,

and there could be no question of fungicidal spraying being either a practical, or an economic, proposition.

At that point, the good people of the Food and Agriculture Organization of the United Nations (FAO) were asked to help, and they invited me to go Ethiopia to direct the research on what appeared to be an insoluble problem. In fact, they had considerable difficulty in persuading me to undertake such a difficult task. However, once in Ethiopia, my colleagues and I soon discovered that, although the coffee crops as a whole were highly susceptible to coffee berry disease, there was great variation among the individual trees. The most susceptible trees lost all their berries several months before harvest time, while the most resistant trees had lost *none* of their berries at the time of harvest. Approximately one coffee tree in a thousand had a very high level of resistance. By travelling all over the country, and looking at about half a million coffee trees, my team of FAO and Ethiopian scientists eventually identified 640 resistant trees.

Coffee in Ethiopia normally ripens in November. In January of 1974, my Ethiopian counterpart, Dr Teklu Andrebahn, and I, were taking a shortcut across a coffee plantation at Agaro, near Jimma, when we found one tree that was loaded with ripe cherries. This was a serendipitous discovery as exciting as Donald Johanson's discovery[1]of the hominid fossil "Lucy" in the Afar Desert.

This single coffee tree was obviously an abnormal type which ripened some 8-10 weeks later than usual. For this reason, the pickers had ignored it, because all the berries were unripe when they were harvesting the crop. Equally obviously, this tree was highly resistant because it was carrying a huge yield of healthy berries, in spite of

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[1]Johanson's discovery was made on November 30th, 1974, in the Hadar Desert, only a few months later, and only a few hundred miles away.

the fact that it was surrounded by susceptible trees, and was growing in an area where coffee berry disease was particularly severe.

Every resistant tree that we found was numbered in chronological order of discovery, with the first two digits indicating the year of discovery. This tree thus became 741, being the first resistant tree to be identified in 1974. It was unusual in another respect also. Instead of being bright red, when ripe, the berries were yellow. Tree 741 turned out to be the best of all the resistant selections. It has now become the principle coffee variety of Ethiopia and I am told that it has been planted on many thousands of hectares.

However, we did not know this at that time and, in the meanwhile, we had many other selections to evaluate. The first harvest of newly identified, resistant trees was kept for seed, and about a thousand seedlings were produced from each resistant tree. Coffee seedlings usually take three years to produce their first berries. During this period, the parent trees were repeatedly visited, and tested for resistance, yield, and cup quality. The progenies from the worst trees were discarded while those from the best trees were retained for further development. These progenies were also tested for genetic uniformity, and only those that were breeding true to type (i.e., those that were already pure lines from natural self-pollination) were kept. And, when the seedlings came into fruit, their resistances to coffee berry disease, and other parasites, were tested, and the horizontal nature of those resistances was demonstrated. About a dozen, highly resistant, high yielding, and high quality, new varieties were selected, and released to farmers only eight years after the disease had appeared. This was an unprecedented achievement in tree breeding, in which it takes many decades to produce useful results, using pedigree breeding methods.

Replacing the old, susceptible coffee crops with new ones in Ethiopia was a huge task. Nevertheless, by replanting with these new varieties, the country was able

to modernise its coffee production with new coffee crops. These were planted in rows to permit mechanical cultivation and to provide easy access to the trees, which were properly pruned to produce high yields. These trees are also so resistant to all the locally important pests and diseases that no chemical pesticides are necessary. The new varieties have not only solved the problem of coffee berry disease. They have led to the modernization of Ethiopian coffee production as well, and the national average yield has been greatly increased as a result.

These new cultivars have done something else. They have provided a clear demonstration of what horizontal resistance can achieve. They have produced a control of coffee parasites that is permanent, complete, and comprehensive. They have also shown that these high levels of horizontal resistance are not in conflict with high yields, a high quality of crop product, and good agronomic suitability. And this coffee is cultivated without any use of pesticides.

Chapter Fifteen

Cocoa

When Hernán Cortés conquered Mexico in 1519, the Aztec Emperor Moctezuma believed Cortés was a god, and he entertained him, with all the luxuries of the land, in his palace at Tenochtitlán, which is now Mexico City. These luxuries included dishes made with cocoa. Because sugar was unknown in the New World, the Aztecs flavoured their cocoa with red peppers and salt.

The Aztecs

The language of the Aztecs is called Nahuatl and it is still spoken by six million Mexicans. The pronunciation of the Nahuatl "tl" sound is best illustrated by an Ogden Nash ditty which runs "When you shake a ketchup bottle, first none will come, and then a lot'l." (Sadly, this ditty is now out of date because ketchup bottles are no longer made of glass. They are made of plastic and a small squeeze will produce all the ketchup you want.) The name *Nahuatl* is thus pronounced Nar-what'l. And the Nahuatl name for savoury cocoa dishes is *molli*, which the Spanish corrupted to *mole*, (pronounced 'mow-lay', with 'mow' as in lawn mower).

Today, *mole* is still popular in Mexico, and it has even been suggested that *mole* is the oldest surviving recipe in the world, because it was already ancient when Cortés first tasted it nearly five centuries ago. There are many modern variants of *mole*, but they all consist of a savoury sauce, flavoured with both cocoa, and a

combination of various kinds of chillies. *Mole* is specially good when served with chicken or turkey.

The Aztec empire consisted of the Aztec nation, in the Valley of Mexico, surrounded by a series of tribute-paying states. Each of these states had been conquered by the Aztecs, who then left them with considerable freedom, provided they recognised Aztec suzerainty, and paid tribute. One of the reasons that Cortés conquered Mexico so easily, with only five hundred soldiers, was that he made allies of the tributary states, and thus gained many additional soldiers. He also had the advantage of steel swords, against which the Aztec armour, made of thick cotton, was useless, and steel armour, against which the Aztec weapons, made of sharp volcanic glass embedded in wood, were powerless. Cortés had other things which the Aztecs had never seen before, such as guns and gunpowder, horses, and killer dogs. These dogs were singularly unpleasant Irish wolf-hounds that had been trained to kill people.

Cocoa does not grow near Mexico City, which is at an altitude of eight thousand feet. The Aztecs obtained their cocoa as tribute, from vassal states with a warm, lowland, tropical climate. Given the distances involved, and the fact that the Aztecs had no roads, wheels, water transport, or pack animals, the cocoa beans which reached Tenochtitlán were worth their weight in gold. One hundred cocoa beans would buy a slave. This is perhaps an indication of the high value of cocoa, rather than the cheapness of slaves.

It was for this reason that cocoa beans became a form of currency in the Aztec Empire, similar to the cowry shells of many tropical islands. But it was a currency that could be eaten. So the consumption of cocoa dishes was a strictly controlled privilege of royalty, the nobility, and a few senior military commanders. Cortés

probably never realised just how honoured he was to be served with cocoa dishes by Moctezuma.

A gift from the gods

The people of Central America valued cocoa so highly that they believed it originated as a gift from the gods. They believed this in much the same way that the ancient Greeks believed that the olive was a gift from the goddess Athena. This Aztec belief was conveyed back to Europe by the Spaniards, and it prompted Linnaeus to give the cocoa plant the name of *Theobroma cacao*. *Theo-broma* is botanical Greek for ‘food of the gods’, and the specific name *cacao* was a corruption of the Aztec name for a cocoa flavoured drink, *cacaua-atl*, that was taken to Europe with the beans. The word chocolate is a corruption of the Aztec *chocolatl* which means a cocoa flavoured solid food, rather than a drink.

The word ‘cacao’ was corrupted into ‘cocoa’ in English. The original spelling was ‘coco’, as in coconut (Chapter 7), and the ‘a’ was added accidentally, because of a printing error in Johnson's dictionary. Since Johnson was considered infallible, many English writers even began, quite incorrectly, to write “cocoanut”. Many crop scientists now refer to the tree as *cacao*, and to the edible product as *cocoa*. However, in common usage, it is entirely legitimate to refer to both the tree and its product as cocoa. In his novel *Vanity Fair*, Thackeray mentions a London meeting house called The Cocoa Tree.

A cline

Theobroma cacao is a native of the Amazon Valley, and its centre of origin is in the upper reaches of the river, in the eastern foothills of the Andes. Wild cocoa occurs throughout the Amazon Valley, covering an area measuring nearly two

thousand miles from east to west. The cocoa species shows considerable variation within this range, with all degrees of difference between the two extremes, which are no longer in breeding contact with each other. Botanists call this kind of variation over long distances a *cline*.

At one extreme of the cline, in the Andean foothills, the wild cocoa shows great variation and the trees are self-incompatible. That is, no tree is able to pollinate itself, and it can set fruit only by cross-pollination, with pollen from another tree. With increasing geographic distance away from this western extreme, the frequency of self-compatibility, and of self-pollination, increases, and the variability between trees decreases. At the eastern end of the cline, at the mouth of the Amazon, the wild cocoa is fully self-compatible and it is rather uniform.

Cocoa was taken from the Amazon to Central America at least three thousand years ago. It has been cultivated since antiquity on the Caribbean coasts from Mexico to the Southern border of Costa Rica. During this period, it changed considerably due to domestication, and this type of cocoa is now known as *criollo*, or creole, meaning "native". This is in contrast to the wild, Amazon Valley type, known as *forastero*, meaning "foreign". A hybrid type was developed in Trinidad and is consequently known as *Trinitario*. This hybridisation occurred when an unknown disease ravaged the Trinidadian crops of *criollo* cocoa in the early eighteenth century, and resistant *forastero* types were introduced.

The eastern extreme of the *forastero* cline, at the mouth of the Amazon River, is called *Amelonado*. Being self-compatible, this cocoa shows little variability and it was this material that was taken to the islands in the Gulf of Guinea, in West Africa, by the Portuguese in the seventeenth century. The British took only a few seeds of this material to Ghana in 1879, and the West African cocoa industry is largely based on this very narrow, and very uniform, genetic base.

Cocoa in Africa

As with so many crops that were moved to a new continent, cocoa flourished in Africa because many of its pests and diseases had been left behind when it was transferred from the New World. As a result, Africa now produces sixty percent of the world's cocoa, and the New World produces only thirty percent. However, the cocoa in Africa suffered from the narrowness of its genetic base, when a new encounter disease appeared, and all the cocoa trees were uniformly susceptible to it. This disease is caused by a virus, and it is called swollen shoot disease. It is a new encounter disease because the virus evolved in Africa, and the cocoa evolved in South America. The obvious way to control this diseases is to widen the genetic base and look for horizontal resistance.

Cultivation

Cocoa is a tree of the tropical rain forest. It needs continuous warmth, and lots of rain. It has a growth habit similar to that of the olive tree in that it has several trunks. It produces new trunks from below ground and, when one trunk falls over or dies, it is replaced by another. With this kind of growth, it is difficult to assess the age of the tree, and some people believe that a cocoa tree can live for ever.

Traditionally, plantation cocoa was cultivated under shade trees because it was believed that the direct sun would damage it. Coffee (Chapter 14) and tea (Chapter 13) were also cultivated under shade trees for the same reason. It was argued that these plants were lower-story shrubs of tropical forest, and that they should be cultivated in as natural a manner as possible. This argument is fallacious because there is a considerable difference between surviving in a wild ecosystem, and producing high yields in a carefully controlled agro-ecosystem. It is now well established that cocoa, coffee, and tea will all yield considerably more if grown

without shade trees, provided that they are given adequate fertilisers, and irrigation if necessary, to support these increased yields.

If the cocoa must be grown under shade, there is one species of shade tree that is particularly useful because it too is a crop. This is the coconut (Chapter 00), which must be planted a few years before the cocoa. The mixed cocoa and coconut produces larger yields than equivalent areas of the same crops grown as pure stands.

Cocoa pods

The cocoa tree is also unusual in its manner of flowering. The flowers are borne directly on the bark of the main branches. They are quite small, and are white or pink in colour. The fruit is a pod, shaped rather like a small vegetable marrow, or squash, some four to twelve inches long. An average pod contains about fifty seeds which are the actual cocoa beans. When a ripe pod is broken open, the seeds are covered in a sugary pulp. This pulp is removed by fermenting the beans, in boxes or heaps, for several days. This process kills the seeds, and the typical aroma and flavour of cocoa then develops.

The beans are roasted in order to improve the flavour, reduce astringency, and darken the colour. Roasting also facilitates the removal of the seed coats, or shells, by cracking and winnowing. The kernels, known as *nibs*, are the true cocoa and these are pounded to produce a paste known as the chocolate liquor. The liquor contains a mild drug called *theobromine*, as well as small amounts of caffeine. For this reason, a drink of cocoa is stimulating, but much less so than either tea or coffee.

Cocoa in Europe

Cocoa was first taken to Spain by Columbus at the conclusion of his fourth voyage to the New World. But, when served with salt and red peppers, it was not a

popular drink and, apparently, the Spanish never adopted its use as a savoury sauce. However, the Spanish did discover that cocoa could be served with sugar and vanilla, or even cinnamon, and that it was then a delightful beverage. It was also a very rare beverage, and the Spanish kept it a closely guarded secret for nearly a hundred years.

The secret was broken when the Spanish Princess, Maria Theresa, married the Sun King, Louis XIV, of France, in 1660. This was the year that Samuel Pepys began his London diary. Coffee houses were already common at that time, and Pepys alludes to them more than a hundred times in the nine years covered by the diary. But cocoa was new, and Pepys refers to it only six times, obviously enjoying it, and spelling it variously as Chocolatte, Jocolatte and Chocolate. On one occasion, he was served chocolate in a coffee house. After Pepys had stopped writing his diary, chocolate houses, similar to the older coffee houses, soon appeared throughout Europe.

In those days, the word ‘chocolate’ meant a hot drink which was prepared from the pulverised cocoa beans, the cocoa liquor. In 1828, C.J. van Houten, in Holland, discovered how to make cocoa powder by pressing out most of the cocoa ‘butter’ from the cocoa liquor. Cocoa powder is much less greasy than the cocoa liquor, and all modern drinking chocolate is prepared from it.

In 1847, the English company of Fry & Sons was looking for a way of utilising the expressed cocoa butter, which was a largely useless by-product. By mixing it with cocoa liquor, they invented eating chocolate as we know it today. In 1876, Daniel Peter made further progress, in Switzerland, when he added dried milk to eating chocolate, and invented milk chocolate.

Cocoa butter is a vegetable fat that is solid at room temperature, but liquid at blood heat. This explains why solid chocolate quite literally “melts in the mouth”, and why hot chocolate is always a liquid, and is either a drink, or a sauce like *mole*.

Solid or ‘eating’ chocolate was originally sold in slabs which were usually grooved to facilitate breaking them into small pieces. However, chocolate is one of the easiest substances to mould, and an endless variety of moulds were devised, so that it could be sold in the shape of various animals, eggs, coins, sculptures, and other shapes.

It was also discovered that certain insect pests were liable to lay their eggs on slab chocolate, and that small grubs would then tunnel their way through it. This problem was solved by wrapping the chocolate in aluminium foil, known incorrectly in those days as “tin foil” or “silver paper”, and this was one of the first commercial uses of aluminium.

Chocolate products

Molten chocolate could also be used to cover various kinds of candies which were then known as ‘chocolates’. The chocolate covering served the double purpose of improving the flavour, and of sealing in the moisture and aroma of the enclosed candy, which became known as the chocolate ‘centre’. Chocolate centres were quickly classified into hard and soft centres, and people tended to develop strong preferences for one or the other.

Hard centres were usually nuts, or a hard candy, such as toffee, and soft centres were usually preserved fruit, such as cherries or dates, or soft toffee, fondant, nougat, marzipan, ginger, Turkish delight, jelly, or a sugar ‘cream’’ which would be flavoured with a fragrance such as mint, coffee, or strawberry. Eventually, liquid centres were developed also, and these included alcoholic liqueurs of various kinds. Chocolates are usually sold as either milk chocolates, or plain (dark) chocolates, and people tend to develop strong preferences in this matter also.

Chocolate is also used widely in the baking and pastry industries. Chocolate cake is a firm favourite, and so are chocolate filling, and chocolate icing, or frosting. Cookies and ice cream are often given a chocolate coating. Chocolate chips are used in cookies and ices. Chocolate puddings, and sweet chocolate sauces, are popular as desserts.

The multiplicity of uses for chocolate reveals a curious blend of ingenuity and conservatism. The conservatism is shown in the rigid adherence to the original formula of cocoa, sugar and vanilla. The only true innovations were van Houten's discovery of cocoa powder, Fry's invention of chocolate, and Daniel Peter's addition of dried milk. The original Aztec idea of savoury chocolate has been totally forgotten, outside of Central America, and the cuisines of the world are the poorer for it.

Recently, synthetic chocolate has been appearing on the market, usually as a coating on ice creams and cookies. It is made with plant waxes, and it is coloured and flavoured with synthetic chemicals. It is entirely edible and quite harmless. Indeed, some people even prefer it to the real thing because it contains none of the enzymes of real chocolate that can upset the stomach of someone with digestive problems. It is easily identified because the label always describes it as “chocolate flavoured coating” or “chocolatey” coating.

Quaker families

In Britain, the chocolate industry was largely in the hands of four famous Quaker families, named Cadbury, Rowntree, Fry and Terry. The brothers, George and Richard Cadbury, were social reformers who were interested in the improvement of workers' living conditions. They built a new town, called Bournville, outside Birmingham, with workers’ houses that had gardens and other amenities. They were

years ahead of their time in introducing pension plans, and other forms of social security, for their workers.

The most famous member of the Rowntree family was Benjamin Seebohm Rowntree who was a pioneering sociologist. His book *Poverty; A Study in Town Life* (1901) became a classic. His chocolate firm also had a pension plan, a five day week, and profit sharing. The Fry family also produced some notable philanthropists.

Hershey

In the United States, chocolate manufacturing was also concentrated in the hands of a famous philanthropist, Milton Snavely Hershey (1857-1945). He spent many years developing his idea of the perfect chocolate bar, now known as the Hershey bar. One of Hershey's industrial innovations was the belief that his chocolate was so excellent that it needed no advertising. In Pennsylvania, he built a chocolate factory which eventually became the largest in the world, and the town of Hershey grew up around it. He and his wife established, and endowed, the Milton Hershey School on a twelve thousand acre estate, to provide both a home, and an education, for destitute orphans.

Cotton

Cotton is the most important of the industrial crops, which are inedible crops cultivated for the sake of a raw material used in manufacturing. Other industrial crops are mainly fibres, such as flax, jute (used in making burlap, hessian, or sackcloth), and hemp (Chapter 21). The most important of the non-fibre industrial crops is rubber (Chapter 12). Tree plantations designed to produce timber are also industrial crops, even if they are not usually called crops and, strictly, are a part of forestry, rather than agriculture.

Food crops are the most important crops of all, and are separated into those which produce human food, and those which produce animal food, known as pasture and fodder crops. Finally, there is a group of non-food crops producing miscellaneous pharmaceutical compounds, drugs, insecticides, flavourings, and perfumes. The most important of this group is undoubtedly tobacco (Chapter 16).

Like yams (Chapter 3), cotton was domesticated simultaneously in the New and Old Worlds, in two separate, but similar cultural developments. Quite apart from the domestication itself, these cultural developments involved two inventions which were crucial to the development of civilisation. These were spinning and weaving.

Weaving

Weaving came first and is one of the oldest of our inventions. It developed at a very early period with the making of baskets from reeds, rushes and canes. A knowledge of basket making appears to be common to every human group, and it is likely that the discovery of basket making predates the original migration of our ancestors out of Africa. It is probable, for example, that the people who migrated across the Baring Strait, and then populated the whole of the Americas, brought a

knowledge of baskets with them. Unfortunately for archaeologists, the remains of baskets and cloth are perishable, and ancient remains are extremely rare.

Baskets have an extraordinary range of uses. They were probably used first in the kind of food gathering which involved relatively large quantities of small seeds or berries. It is likely that baskets were used for harvesting wheat that had the shattering character (Chapter 6), for example. There can be no doubt that baskets were a very early, and an essential, aid to hunter-gatherers who were carrying food to a home base. Food storage in baskets would be an obvious development from food carrying. Gradually baskets became increasingly useful in a wide range of domestic uses.

Baskets can even hold water when made with a tight weave of materials, such as rushes, which expand when wet. For the same reason, canvas is waterproof when it is wet, and this is why it can be used for fire hoses, and for water bottles. Waterproof baskets are common in Africa, and are used frequently for brewing and drinking beer. The Hupa people of Northwest California even boil water in such baskets, by dropping hot stones into the water.

Basket weaving techniques are also used in building, and this is the basis of the ‘mud and wattle’ or ‘wattle and daub’ construction, in which a weave of sticks, the wattle, is covered in mud. This is one of the oldest building techniques, and it is still in use today in many parts of the world, particularly in Africa. Walls built in this way are strong and, provided they are kept dry, they are also quite durable.

Basket weaving techniques are also used in making such things as wickerwork, rattan furniture, fish traps, and even boats. The ancient British coracle was a basket covered with skins. The boats of Lake Titicaca, in South America, are made of woven reeds. And the *gufa* boats of the River Tigris are made of woven reeds caulked with bitumen.

A special aspect of weaving, approximately halfway between baskets and cloth, was the weaving of nets. Nets were invented at a very early date, and their importance lay in the catching of fish. Our modern fish industry represents the only ancient hunting activity that has survived to the present, as an important source of food. And it is still totally dependent on the use of nets, which also rank among our oldest inventions.

The step from baskets to the weaving of cloth was an obvious one, but it depended on fibres which were much finer, and more flexible, than those normally used in baskets. The first net and cloth fibres were obtained from the stems of plants such as hemp, abaca (Chapter 19), jute, and flax. The stems would be left to rot in water in a process known as ‘retting’, which would destroy all the plant tissues except the fibres. Flax produces the finest of these fibres, and it is still woven to produce linen. But, in general, stem fibres are too coarse for cloth, and produce either matting or rough cloth, such as sackcloth and canvas. In Mexico, the large leaves of *Agave sisalana* provide coarse fibres called sisal, used since ancient times to make cord and rope.

Spinning

The invention of spinning permitted the utilisation of much finer fibres. Cotton provides the only plant fibre fit for spinning to make cloth, but animal fibres include the wool of sheep, goats, alpaca, and llama and, the finest of them all, an extrusion produced by that extraordinary insect, the silk worm.

Spinning allows short fibres, such as wool and cotton, to be joined together to form a thread of unlimited length, called ‘yarn’. With long fibres, such as stem fibres, silk, and the synthetic extrusions, spinning is used only to twist several fibres together

in order to produce a thicker yarn. Yarns can be spun together to produce twine. And twines can be spun together to produce rope.

The most primitive spinning is done by hand, using two sticks known as the distaff and the spindle. The distaff holds a mass of fibres from which the material to be spun is slowly drawn. This thread is wound on to the spindle which hangs from it, and the spindle is rotated to produce a twist. The twist is then wound on to the spindle, and the process is repeated.

Later, the spinning wheel was invented in India. The distaff and spindle were mounted, in order to leave the hands free. The spindle was held in bearings and was rotated with a belt linked to a large driving wheel. There was thus a big gearing in which a slow rotation of the drive wheel produced a rapid rotation of the spindle. The spinning wheel was introduced to Europe in the Middle Ages where it was improved by a foot pedal, and the conversion of the spindle into a bobbin.

The Industrial Revolution

With the beginnings of the industrial revolution, in eighteenth century Britain, spinning began to be mechanised. The 'spinning Jenny' was patented by James Hargreaves in 1770. Sir Richard Arkwright produced an improved machine in 1779 and, finally, Samuel Crompton produced a machine called a 'mule', also in 1779, which greatly increased productivity, and became the basis of all modern spinning machines.

The power loom was a much more difficult proposition. It was developed by Edmund Cartwright who, incredibly, was a clergyman, and was rector of Goodby Marwood, near Melton Mowbray, in Leicestershire. He was one of those delightfully perverse characters who knew nothing of machinery, but who set out to build a power

loom for the simple reason that he had been told it could not be done. He patented his machine in 1786.

It was these spinning machines, along with mechanical looms, that led to organised bands of craftsmen in England called ‘Luddites’, named after a mythical Ned Ludd, known as ‘King Ludd’. The Luddites wore masks and operated at night. They carefully avoided violence to people, but their intent was the destruction of the new textile machinery that was putting them out of work.

The movement was ruthlessly suppressed by the authorities, and many of its members were either hanged, or transported to Australia. It finally disappeared in the wave of prosperity that developed with the industrial revolution, but the movement gave its name to all subsequent reactionaries, who automatically oppose any technical development that is new.

This textile machinery represented the beginnings of the industrial revolution. Initially, it involved wool, and the cloth industry was centred on Yorkshire. Later, cheap cotton imported from the United States dominated the cloth industry which then became centred on Lancashire, and the Port of Liverpool.

All this machinery depended on power, and the old water power of a water mill was quite inadequate. The industrial revolution would have been impossible without the development of the steam engine. The first rotary steam engine to be installed in a textile mill was at Robinson’s mill at Papplewick, in 1788, in Nottinghamshire. However, an important secondary effect of steam was that it was no longer essential to locate mill towns in inaccessible, hilly sites where water power was available. Nor did the steam powered mills have to be closed down during a drought.

Entire towns grew up, either from nothing, or expanded beyond recognition, close to the port of Liverpool, and the new canals that emanated from it. These cotton towns included Manchester, Rochdale, Burnley, Wigan, and Blackburn.

The benefits of manufacturing depend on the ratio of the value of the finished article, to the value of the raw material. This ratio is very high with, say, sand as a raw material, and computer microchips as the finished article. But it is very low with relatively expensive raw cotton, and relatively cheap cotton cloth. For this reason, the cotton factories of today are mostly located in the non-industrial world, and the old cotton towns of Britain are now a depressed area.

Even in its heyday, the textile industry in England was fraught with poverty and despair. As mechanisation increased, wages decreased, and the old hand weavers and cottage industries went out of business. Labour was exploited quite ruthlessly, and this was the worst period of such things as child labour, "dark satanic mills", and the writings of Marx and Engels, concerning the evils of the capitalist system.

Eli Whitney

The other side of this coin was the supply of the raw cotton itself which, in the first half of the nineteenth century, came exclusively from the United States, and was dependent on slavery. The development of the cotton crop had also hinged on the invention of a new machine. In 1793, Eli Whitney, of Massachusetts, was visiting the South where he was told of the difficulty of removing cotton seeds from cotton lint.

This essential step was done by hand, and it was so labour intensive that cotton cultivation was scarcely an economic proposition, even with slaves. Whitney was a mechanical engineer and, then and there, he invented the cotton gin, a machine that used wire hooks on a revolving drum to pull the lint through slits too narrow for the seeds. (The term 'gin comes from the word 'engine', and it should not be confused with the alcoholic drink of the same name, which is a corruption of the French *genièvre*, meaning juniper, which gives gin its characteristic flavour.) It is said that

Whitney got the idea of his cotton gin from watching a cat trying to claw a chicken through the slats of a fence. The cat got feathers, but no chicken.

Whitney's invention permitted the cultivation of cotton, in States such as North and South Carolina, Georgia and Tennessee. There is no doubt that he played a key role in the development of cotton production, in bringing prosperity to the South, and in the inception of the massive use of slavery.

But there is an incredible irony in Whitney's career as a mechanical engineer. He later opened a factory in Hamden, Connecticut, which was the first with a product that had inter-changeable parts. He was manufacturing muskets and, previously, each part had to be shaped by hand to fit its own musket. If a part broke, the entire musket was useless until a craftsman had made a new part specially to fit it.

There was great scepticism about Whitney's inter-changing parts and, to overcome it, he arranged a demonstration in Washington in 1801. In the presence of President-elect Thomas Jefferson, he allowed spectators to select musket parts at random from heaps of components and then assemble complete muskets. This has often been described as the inauguration of the American system of mass production.

The irony of Whitney's career is that his inventions were responsible for the cotton production and slavery of the South, as well as the musket production, and much of the manufacturing potential of the North. Whitney died in 1825 and, fortunately for him, he never lived to see the conflict between his two greatest inventions, which occurred with the American Civil War.

Many English cloth manufacturers were ruined when the supply of cheap cotton was disrupted during the American Civil War, and the North blockaded the South. In Britain, this period (1861-65) was known as the 'Cotton Famine'. At that time, my own grandfather was studying in Manchester University to become a doctor of medicine when his father, who owned a cotton mill, went bankrupt. My

grandfather was compelled to abandon his studies, and to take work as a clerk. But, in spite of such problems, the majority of English people supported the North, and the abolition of slavery, rather than the South, and cheap cotton, produced by slaves.

Slavery

The abolition of slavery required two separate actions. The first was the abolition of the iniquitous slave trade itself. This was a triangular trade, taking goods from Europe to Africa, slaves from Africa to the New World, and goods from there, back to Europe. In the slave ships, the slaves were chained to the deck, to prevent them from rioting, or jumping into the sea. Their living conditions were so appalling that as many as twenty percent of them would sometimes die during the voyage.

The second step was the emancipation of existing slaves. The chief problem here was an economic one. The slaves themselves represented a huge capital investment, and some form of compensation of slave owners was considered just. But there was another difficulty because, after emancipation, the work previously done by slaves had to be paid for with hired labour, and the costs of production were dramatically increased. The opposition to the abolitionists was powerful.

The first abolitionists were the Quakers, who are among the most genuine and sincere Christians who ever lived, and whose first criticism of slavery began as early as 1671. William Wilberforce was the principle leader of the anti-slavery movement in England. In 1807, the slave trade to British colonies was prohibited and, in 1833, Parliament took the second step and passed a law freeing all slaves in British colonies, and providing monetary compensation to their owners.

The United States also prohibited the slave trade in 1807 but slave ownership and slave smuggling continued in the South. Slavery became a constitutional issue of such importance that it led to the American Civil War. Slave smuggling was so

rampant that, in 1850, more than 50,000 slaves a year were being taken from Africa to the Americas. This smuggling did not cease until the United States, in 1862, signed a treaty conceding the right to British naval forces to search American merchant ships. It was only then that the slave trade finally stopped and, with the victory of the North in the Civil War, all the slaves in the United States were emancipated, by the Thirteenth Amendment to the Constitution, in 1865.

The effect on the cotton industry was irreversible. In efforts to overcome the cotton famine, seed of the superior American cotton, known as Upland cotton, was taken to virtually every country of the world where it might flourish. This created competition for the Southern States where none had existed before. This was because most cotton producing countries began to replace their inferior Old World types with the superior Upland cotton. And the competition became even more painful because the cotton growers in the Southern States now had to pay their labour.

Mechanisation

Compared with wheat harvesting machinery (Chapter 6), mechanical cotton pickers proved very difficult to develop, and they did not come into use until the 1940s, when two different types were introduced. Spindle pickers collect the cotton from the open bolls on to spindles which are wet, and the lint sticks to the damp surface. Stripper harvesters collect everything removable from the cotton plants, including the bolls, and a lot of leaves, and other plant parts. The cotton is separated from the rubbish during a separate screening process after harvest. This type of harvesting is facilitated if the crop is first sprayed with a defoliant chemical, which causes all the leaves to fall, and which also promotes uniform ripening of the bolls.

Cotton lint is hair that develops on the seed, and a number of seeds are enclosed in each seed capsule, called the ‘boll’. Cotton seeds have two kinds of hair,

and each hair consists of a single plant cell. One kind of hair, known as fuzz, is quite short and is almost solid cellulose. Fuzz is often a nuisance because it carries a disease called bacterial blight. To prevent this disease, the seed used to be soaked in sulphuric acid to destroy the fuzz. However, less drastic treatments are now available. With modern machinery, the fuzz can be removed and utilised for the manufacture of non-woven cloth, such as felt.

The other kind of hair is called lint, and is the cotton of commerce. These hairs are also made of cellulose, but the cells are hollow, and they collapse on drying to produce long, convoluted, flat ribbons. They are produced profusely all over the surface of the seed, and they are easily removed.

Cellulose

Both lint and fuzz consist of pure cellulose, which is the material of the walls of plant cells. Cellulose can be dissolved in solvents such as amyl acetate and, when the solvent is evaporated off, the residue is a clear film, known as celluloid or cellophane. Celluloid has been used in the manufacture of such diverse articles as photographic film, the artificial silk called rayon, synthetic sausage skins, and wrapping film for food and cigarette packets. However, the value of celluloid has been greatly reduced by the development of modern plastics. When dissolved in nitric acid, cellulose forms an explosive known as gun cotton. Cleaned, unspun lint is known as cotton wool.

Origins

The production of lint by the cotton plant is the result of a mutation that first occurred in Africa, in cotton known technically as the ‘A-genome’. All other wild cottons were lint-free, and this mutation would quite possibly have disappeared, had

it been left to nature. In fact, it was carefully preserved, and utilised, repeatedly and independently, by different peoples, with different cultures, all over the world.

The origins of the domesticated cotton plant are complicated and the account given here is a deliberate over-simplification. Cotton was first cultivated and domesticated in Africa using the 'A-genome' which is the source of all lint-forming cottons, and which now consists of two diploid species, *Gossypium herbaceum* and *Gossypium arboreum* making up about a dozen cultivated 'races' in Africa and Asia. The earliest archaeological record of this kind of cotton, in the Old World, is from the Indus Valley civilisation, and dates from about 3000 BC.

The earliest record of cotton being spun and woven in Africa belongs to the Meroë people, an ancient Nubian kingdom, which existed from 650 BC until 350 AD, on the upper reaches of the Nile in modern Sudan. However, because cotton cloth is so perishable, its absence from earlier archaeological records means little.

New World cotton is a hybrid between the indigenous 'D-genome' of South America, and the 'A-genome' of Africa. This hybrid between two diploids has four sets of chromosomes and is a tetraploid, known as the 'AD-genome'.

It seems that this natural hybridisation, which produced the 'AD-genome', happened twice, to produce two different hybrids, and two different, wild South American species of linted cotton. One of these wild hybrids is *Gossypium barbadense* which was domesticated by people in western South America, in 2000 BC or earlier. The other is *Gossypium hirsutum* which was domesticated and cultivated in Mexico, possibly as early as 3500 BC.

The other cotton genomes are all wild diploid species which do not form lint. The B-, E-, and F-genomes occur mainly in Africa and, occasionally, Asia, and the C-genome is Australian. They are of interest in breeding experiments but otherwise have no economic importance.

Just how the African ‘A-genome’ reached the New World has been the subject of much controversy, with various more or less fantastic hypotheses suggesting that it was taken there by ancient people sailing either across the Pacific from India, or China, or across the Atlantic from Africa. For botanical and archaeological reasons, this must have happened at a date which is impossibly early, in about 4,500 BC.

The most likely explanation lies in the fact that the seeds of ‘A-genome’ cotton are covered in lint and, consequently, they float. They can survive for up to three years floating on sea water, and it is probable that ‘A-genome’ seeds floated across the Atlantic, in much the same way as the bottle gourd (Chapter 2).

The domesticated Mexican cotton was taken to the United States in 1700 where two further domestication processes occurred. These were the early-fruiting habit, and the annual habit. This new cotton became known as ‘Upland’ cotton, to distinguish it from the older, lowland, ‘Sea Island’ cotton, and it became the basis of the American cotton industry. As we have seen, Upland cotton was taken to most other tropical and subtropical countries, when the cotton supply from the Southern States was disrupted during the American Civil War. It is now the principle cotton of cultivation throughout the world, having largely replaced all the inferior, Old World cottons.

Sea Island cotton has a superior, long staple, but it is more difficult to produce. It is derived from *Gossypium barbadense*, possibly with some hybridisation with Upland types. Egyptian cotton, known as Jumel's cotton, is a very similar, superior, long staple cotton, which is derived from a single plant found in a Cairo garden in 1820. About a billion pounds of it are now produced each year in Egypt.

Production

World production of cotton is about twenty five billion pounds grown on about eight million acres. The United States produces the most, followed, in descending order, by China, Russia, India, Egypt, and Mexico. The main importing countries are Japan, Western Germany, France, Britain, and Italy.

The worst pest of cotton is the boll weevil, *Anthonomus grandis*, which is a native of Mexico. The boll weevil was observed in Texas in 1892 and it subsequently spread, as a re-encounter parasite, to all the cotton producing areas of the United States. In addition to the boll weevil, there are about 150 other pests of cotton, and many diseases cause by microscopic fungi, bacteria, and viruses. One of the reasons for these high levels of parasitism is that much cotton breeding, like potato breeding after the discovery of Bordeaux mixture (Chapter 11), has been conducted under the protection of insecticides and fungicides. As a consequence, considerable resistance to pests and diseases has been lost.

An important by-product of the cotton crop is the cotton seed, which is usually processed to provide cotton seed oil (Chapter 9), used in margarine manufacture, and for cooking and salad oils. The residue, after the oil has been extracted, is cotton seed cake, which is used mainly for feeding cattle. Unfortunately, both the oil and cake contain a toxic compound called gossypol. This is not poisonous to ruminant animals, such as cattle, but it is poisonous to non-ruminants, such as poultry, pigs, and people. The gossypol can be removed chemically but this process is expensive, and one of the more important objectives of cotton breeding is to produce a gossypol-free cotton seed.

Cotton reached its maximum importance in the period 1924-28 when it provided almost eighty five percent of the world's textiles. Since World War II, and

the development of cheaper synthetic fibres from plastics, such as nylon, cotton production has been under a constant threat.

However, cotton remains the most comfortable cloth when worn next to the skin. This is because it readily absorbs sweat, and evaporates it to the atmosphere. At the same time, when dry, cotton cloth is an excellent heat insulator. It thus provides garments which are both cool in hot weather, and warm in cool weather. Cotton does not cling to the skin, like nylon cloth, nor is it itchy, like wool. Being made of cellulose, cotton cloth can readily be printed with fast dyes, in an infinite variety of patterns, designs, and colours. Cotton also lends itself to a wide variety of weaves, including towelling, or terry cloth.

Several factors have contributed to the popularity of cotton in spite of competition from the synthetic fibres. First, various new methods of treating cotton cloth have eliminated its main disadvantages. Modern cotton cloth does not shrink, and it does not wrinkle. Consequently, it can be washed and dried in home washers and dryers without damage, with a minimum of work, and with no need for ironing. Second, cotton is in demand for blending in cloth made from synthetic fibres to improve their ‘feel’ and comfort. Third, the most popular kind of clothing these days consists of jeans and jackets made from denim, a name derived from the French *serge de Nîmes*. And denim is made from cotton.

Chapter Seventeen

Sugar

Sugar Beet

There is a wild plant that grows on the sea shore of many European countries, known as 'sea beet', and its Latin name is *Beta vulgaris* sub-species *maritima*. The ancient Romans knew about it, and Linnaeus named it after the medieval word for it, which was *beta*. However, this word has no connection with the Greek name for the second letter of the alphabet.

This wild beet has produced an extraordinary number of cultivated plants. First and foremost is the sugar beet, now grown on huge acreages, and its various garden relatives such as the deep red beetroot, known as garden beet in the United States. The fodder beet, or mangolds, used for animal feed, are of special historical significance, and are also derived from it. So are various leaf beets, such as Swiss chard, that are used as a green vegetables. The common spinach is only a distant relative which, however, belongs to the same botanical family (*Chenopodiaceae*).

It is probably the chards and red beetroots that are the oldest beets to be cultivated. In the fourth century before Christ, Aristotle mentioned red chards, and Theophrastus described both light and dark green chards. Red beetroots were mentioned in various Roman recipes of the second and third centuries, and the Romans also used them for animal feed. They were mentioned in English recipes as early as the fourteenth century and they were introduced to the United States in the eighteenth century.

However, there were two kinds of beet that were both influential in western history. The first was fodder beet which transformed both European agriculture and

the oriental spice trade. The second was sugar beet which, to this day, is a crop of strange political importance.

As mentioned in Chapter 10, farmers in Europe, during the Middle Ages, had no satisfactory means of feeding their farm animals during winter. Cattle, horses, sheep, and goats needed grazing and, if the ground was frozen or covered in snow, there was no grazing to be had. In any event, pasture plants do not grow in winter and those that were grazed would not regenerate until the spring. Hay was available, but a prohibitive amount of grazing land was needed to produce enough hay to feed full size herds throughout the winter.

Agriculture was transformed with a new winter fodder crop for farm animals, which consisted of fodder beets, known variously as beet, mangolds, mangel-wurzels, and just plain "roots". In addition, the common turnip (which is a relative of mustard, and is not related to beets) was also developed into a winter feed for farm animals. Each of these new root crops provided a double source of animal food. The leafy tops could be grazed off in the late autumn, and the roots would provide fodder throughout the winter.

This use of fodder crops began in Norfolk, England, with a new system of crop rotation known as the 'Norfolk four-course'. Until then, medieval agriculture had used the 'crop and fallow' system in which a crop would be grown and, in the following year, the land would be left fallow, being merely ploughed two or three times to kill weeds. This medieval system was not very productive, mainly because half of all the land was out of production all the time. On very good soils, it was sometimes possible to grow crops for two years out of three but, even so, one third of that land was out of production.

The importance of the Norfolk four-course was that it brought all the land into production, all the time. In effect, this doubled the agricultural production of a given area. It also doubled the carrying capacity of the environment.

However, this progress in agricultural production was only possible after the old feudal relationships between land owner and peasant had been broken. This happened first in western Europe, particularly in Britain and Holland. The combination of a doubled food production, and a liberated workforce, eventually led to the industrial revolution. This happened first in Britain because of her natural resources in coal and iron. It happened considerably later in Germany because feudal relationships persisted longer in that country. And it happened last of all in Russia where serfdom was not abolished until 1850.

With the Norfolk four-course, wheat would be grown in the first year, turnips or beet in the second year, barley in the third year, under-sown with clover and rye grass, and, in the fourth year, the clover and rye grass would be either grazed, or cut for hay. The rotation would then be repeated.

In addition to bringing all the land into production all the time, this new system of rotation led to other increases in productivity. First, it permitted the feeding of relatively large herds of cattle, and flocks of sheep, during the winter months, and this resulted in vast improvements in both the quantity, and the quality, of the meat supply. A secondary effect was the greatly increased quantities of animal manure, and this led to an improved soil fertility. The rotation itself was an effective method of reducing many crop pests and diseases, particularly the host-specific, soil-borne parasites of plants. With improved fertility and reduced crop parasites, the yields of the wheat and barley were improved.

Another important factor, which was understood scientifically only much later, was the use of clovers in the rotation. All cultivated plants which belong to the

botanical family *Leguminoseae* are known as ‘legumes’. These crops include all the beans and peas, usually called grain legumes or pulses, and all the clovers and related plants, such as alfalfa, known as fodder legumes. A characteristic that all legumes have in common is the ability to fix atmospheric nitrogen, and convert it into plant protein.

This chemical process takes place in small nodules on the roots. The nodules are formed by special bacteria, called *Rhizobium*, which live symbiotically with the legume. The bacteria receive sugars from the legume, and they provide protein in exchange. The chemistry of this process is still not understood. A similar effect can be achieved in a nitrogen fertilizer factory only at very high temperatures, and with the consumption of large amounts of energy. *Rhizobium* does the same job at soil temperatures, and with the consumption of very small amounts of energy.

Industrial chemists would love to be able to copy the *Rhizobium* process but, so far, the secret has eluded them. One of the few things we know about this secret is that the *Rhizobium* nodules contain a red substance called haemoglobin which is almost identical, chemically, to the red pigment of human blood. However, this is a digression. What matters is that legume root nodules add nitrogen to the soil, and this improves the yield of other crops, such as the barley and wheat in the Norfolk four-course.

The development of the Norfolk four-course represents the transition from medieval to modern agriculture. It became possible only because of a new system of land ownership. In medieval agriculture, most land was owned in common, and the land was cultivated in long strips, each of about an acre in size. Each farmer would own the crops of several strips, scattered throughout the area of the common land. Each strip would be cultivated on a crop-fallow rotation, and the yields were

abysmal. The sheep and cattle would be grazed on another area of common land and, as we have seen, most of them would have to be slaughtered with the onset of winter.

In the fourteenth century, the population of Europe was beginning to exceed the carrying capacity of the environment. There was considerable threat of famine which the inefficient agriculture did little to ameliorate. It was at this point that the plague struck Europe, and about one third of the population died. It is very probable that the effects of this disease were aggravated by malnutrition.

The new system of land ownership resulted from “enclosure” in which common ownership changed to single ownership. This became politically possible only because the plague epidemics had killed so many people and, even then, the enclosures were bitterly resented. Nevertheless, the loss of people meant that large areas of land lay abandoned, and they were taken over by surviving, and enterprising, individuals for the grazing of sheep.

In England, this proved so profitable that the enclosures were legalized by Acts of Parliament, and the export of wool and woolen cloth became the country's main source of wealth. Many of these land-grabbing farmers grew so rich and powerful that they were ennobled by the king and, later, they became the great aristocratic Whig families that governed the country for several centuries. They were finally divested of power by the even wealthier manufacturing classes which emerged from the industrial revolution.

The agricultural breakthrough in the use of fodder crops, and the Norfolk four-course, with the resulting decline in the demand for spices, occurred quite slowly, but nearly three more centuries were to elapse before the vulgar beet became responsible for a second change in the course of history. In 1747, a German chemist, Andreas Sigismund Marggraf, detected sugar in the sap of fodder beet, and he

managed to crystallize it. He must consequently be regarded as the father of the beet sugar industry.

Marggraf was a curious mixture of the ancient and modern. He was the last eminent chemist to believe in the phlogiston theory, which was so dramatically wrong in its postulation that fire was an element which was lost when substances burned. Yet he was the first chemist to use a microscope for chemical research, particularly for distinguishing small crystals, such as sugar crystals.

In those days, no distinction was made between chemists and plant breeders, and Frederick the Great, King of Prussia, commissioned Marggraf to improve the quality of German tobacco. This plant breeding work did not prevent Marggraf from making other notable achievements in physics and chemistry. He was the first to observe the relationship between thermal conductivity and electrical conductivity, and he also invented the platinum crucible.

It was Marggraf's pupil, Franz Karl Achard, who developed a sugar extraction process for beet, and who established the first factory for the manufacture of beet sugar, at Kunern, Silesia, in 1801. He received a subsidy from Frederick the Great who gave him a ten-year monopoly for the manufacture of beet sugar in Prussia. He also opened a school to teach beet sugar production methods.

At the beginning of the nineteenth century, most of continental Europe was ruled by Napoleon and, because Napoleon was at war with Britain, continental Europe was feeling the effects of the British naval blockade. One of the most noticeable of these effects was the shortage of sugar which, at that time, was produced from sugarcane, mainly in the West Indies. In 1801, a French banker, Benjamin Delessert, who had opened the first savings bank in France, opened the first cotton factory. A year later, he opened the first beet sugar factory. He was a man of

extraordinary initiative who also founded several charities, as well as societies for the promotion of learning.

In 1811, Napoleon acted on Delessert's initiative and issued a decree which set aside 32,000 hectares of land for sugar beet production. He established six special schools for the study of sugar beet, with a hundred scholarships, and he constructed ten new beet sugar factories. He also established bounties to encourage peasants to grow beet.

By 1814, forty beet sugar factories were in operation in France, Belgium, Germany and Austria. The beet sugar industry in continental Europe had become firmly established and vested interests had already developed. After the war ended, with Napoleon's defeat at the battle of Waterloo, in 1815, and the British blockade was lifted, the import of sugar into France, and other countries, was restricted by tariff barriers. This was done in order to protect the young beet sugar industry from the much more competitive cane sugar produced in the colonies. Sugar had become a political commodity.

Sugar beet refineries are expensive and, once they have been built, usually in times of war, it is very tempting for governments to protect them with tariff barriers. But to encourage beet is to discourage cane, discussed below, at the expense of the non-industrial world. The protection of the beet sugar industries in rich industrial nations, which piously preach development of the non-industrial world, is nearly as reprehensible as their taxation of tropical products such as tea and coffee.

At the beginning of the nineteenth century, sugar from the West Indies was the largest import into Europe. Tropical sugarcane had a far higher yield than sugar beet. Even now, after impressive increases in the yield of sugar beet, sugarcane usually has about double the sugar yield of sugar beet. With its continuous, year-round growing season, lower inputs, and low wage labour, cane sugar is also much cheaper than beet

sugar. During times of war, or a world glut in sugar, it has always been the poor, tropical countries that suffered the most. But, because of their the protective tariffs on sugar, the rich countries have kept more efficient, tropical producers poor, ever since the Napoleonic wars, and even during times of peace. This deprivation has lasted almost two centuries.

Consumers in the rich countries have also suffered unnecessarily, for the whole of this period. During the 1980s, for example, beet sugar producers in Europe, Canada, and the United States were paid four to five times the world price. The world price was depressed mainly because, for years, the Soviet Union was taking large quantities of sugar from Cuba, and then dumping it on the world market. Although sugar beet has certain advantages, such as using the leaves and root residues for feeding sheep and cattle, and for crop rotation, these cannot justify this economic imbalance.

Curiously, the effect British war blockades on the supply of sugar was reversed during both World Wars, when the German U-boats greatly encouraged sugar beet production in Britain, mainly because shipping was so scarce, and was required for supplies more important than sugar. So Britain, too, has its own sugar beet industry.

In the days of Marggraf, who was working with fodder beet, the sucrose content of beet was only 3-4%, and the yield of the roots themselves was relatively low. Modern sugar beet contains up to 16% sucrose, and has a much higher yield of roots. This is an extraordinary four-fold increase in sugar content and, obviously, without it, and without the increased root yields, sugar beet could not have been an economic proposition today. These increases also indicate just how superior sugarcane was to sugar beet, at the time when sugar tariffs were first imposed.

Sugarcane

Sugarcane is a grass, approximately halfway in size between the small cereal grasses, and the biggest grasses of all, which are the giant bamboos. It has thick stems, usually one inch or more in diameter, which contain a juice rich in sugar. At the time of harvest, the cane is cut, stripped of leaves and taken to a factory. The cane stems are crushed under great pressure, in a series of huge rollers, and the cane juice runs into tanks below.

The pressure of these rollers is so great that the remaining fibrous material is dry enough to burn. It is called *bagasse*, and it is used either as fuel for the steam boilers, or for the manufacture of low grade paper and board. In the old days, the rollers were driven by steam engines, often with a flywheel that was twenty feet in diameter, and half hidden in a special well in the floor. These days, diesel engines are used but the cane crushers are still an impressive sight.

The juice is cleaned through filters and it is then boiled, often under vacuum, to remove most of the water. As the concentration of sugar increases, it begins to crystallize. The sugar crystals are removed, and they are rinsed in a centrifuge similar to the domestic spin dryer used for clothes.

This sugar is the so-called brown sugar, often referred to as raw sugar. To make white sugar, raw sugar must be refined a second time. It is dissolved in very clean water, carefully filtered and clarified, re-crystallized, and then washed and dried.

A large cane sugar factory produces raw sugar by the thousands of tons. The sugar is usually stored on a concrete floor in a warehouse as large as an airplane hangar, and it is handled with power shovels and trucks designed originally for earth moving. In the past, it would be shipped to an industrial country for refining and, because bulk raw sugar tends to set hard like concrete, it used to be bagged in sacks.

It was later discovered that this expense could be avoided by reducing the moisture content and, today, raw sugar is routinely shipped in bulk. Increasingly, also, the final refining and packing is being done in the producing countries.

Various kinds of white sugar are recognized, and they are classified according to the size of the crystals. White sugar can also be milled to a fine powder to produce the sugar used for ‘icing’ or ‘frosting’ cakes. And it can be wetted and allowed to dry in blocks which are then cut up to produce cube sugar.

The remaining cane juice that is left over after the raw sugar crystals have been removed is called *molasses*. It contains a mixture of other sugars which will not crystallize and, consequently, these sugars can be utilized only in liquid form. The molasses can be purified and concentrated by evaporation, and it is then sold as a syrup, often called ‘golden syrup’, for human consumption, or as an additive to animal feed. Alternatively, it can be fermented, and distilled, to produce the spirit known as rum. White rum has come straight out of the still and is the purest. Brown and dark rums have had various substances, usually burnt sugar, added to them for flavouring and colouring.

Sugarcane is a tropical plant and it thrives in the hot and moist climate of tropical islands. It originated in the islands of the Southwest Pacific, most probably in New Guinea where it is cultivated mainly as ‘chewing cane’. Pieces of stem are peeled and chewed for their sugar. The cane tissue itself is not edible and, once it has been drained of its sweetness, it is discarded, like spent chewing gum. For people in the very early stages of cultural development, who lacked any form of candy, or sweet food, chewing canes must have been a greatly prized crop. To this day, country people chew cane throughout the tropics.

The chewing canes of New Guinea are known as ‘noble’ canes because of their thick stems, high sugar content, and few fibres. It is thought that they were

domesticated from a wild cane, *Saccharum robustum*, which, as its name implies, is a very robust grass, growing up to thirty feet tall, but which contains little juice, and little sugar.

There are four reasons for thinking that the noble canes are of very ancient domestication. First, they are very different from their wild progenitor, particularly in their domestication characteristics of juiciness and sweetness. Second, noble canes, like modern wheat and maize, cannot survive on their own in the wild. They are dependent on cultivation by people for their survival. Third, noble canes have lost the natural ability to propagate themselves by seed. Except on research stations, they can be propagated only vegetatively, by cuttings. Lastly, there is an astonishingly wide range of varieties of noble cane in the centre of origin, with an assortment of colours and striped stems that would rival a modern candy store for flamboyance.

In antiquity, noble canes were dispersed, just like coconuts (Chapter 9), by the seafaring Austronesians who inhabited the many thousands of islands of the Southwest Pacific. When Austronesians first migrated to Hawaii, in about 600 AD, they took noble canes with them. Noble canes also reached Southeast Asia at an early date, and they have been present in Malaysia and India since ancient times.

It is probable that the art of extracting sugar from sugarcane was first developed in India, where there was an even more ancient tradition of making sugar from palm sap. This kind of coarse, unrefined sugar is known as *jaggery*, and is still made in small jaggery factories in country districts throughout the tropics. To make jaggery, the juice is extracted by crushing the cane, and it is then boiled to increase the concentration of sugar. The hot juice is poured into flower pot shaped moulds, and it is left to cool and crystallize. The mould is then turned upside down in order to drain off the molasses. This kind of sugar, which is usually a very dark colour, is also known as ‘loaf’ sugar.

It is thought that an accidental hybridization occurred in Northern India between a noble cane and a wild relative called *Saccharum spontaneum*. This produced a new species called *Saccharum barberi* with thinner, harder stems. These hybrid canes were better suited to the subtropics, and high altitudes, where noble canes do poorly. Although they produce less sugar, they are more hardy, and more resistant to pests and diseases, than the noble canes. It was a form of these hybrid canes that was taken to China in ancient times and, later, another form was taken to Persia (modern Iran), and Europe.

Many of these events can be dated from historical records. Alexander the Great saw sugarcane and sugar during his conquest of northern India in 326 BC. The Greeks called it "honey from reeds". In the first century AD, Dioscorides wrote of "a honey called sakkharon collected from reeds in India and Arabia Felix (modern Yemen), with the consistency of salt, and which could be crunched between the teeth". This "sakkharon" was traded in Alexandria at that time, but the sugarcane plant itself did not reach the Mediterranean until the Arabs conquered Egypt, and introduced it in 641 AD. This was the period of the lightening Arab conquests, and they took sugarcane with them all the way across North Africa, into Spain where, some five hundred years later, they were cultivating 75,000 acres of sugarcane.

The Portuguese took sugarcane to Madeira, the Canary Islands, the Azores, and West Africa. On his second voyage, in 1493, Columbus took sugarcane to Hispaniola (Dominican Republic) where, however, these founder populations of both cane, and Spanish colonizers, that he left behind, were exterminated by Caribs. West Indian sugar was first produced in Hispaniola in 1506 and, by 1550, it had been taken to most of the tropical New World.

In the course of this transfer of sugarcane from India, across Eurasia, Africa, and the Atlantic to the New World, two quite typical things happened. The first was

that virtually all the pests and diseases of sugarcane were left behind. The sugarcane industry of the New World then had an enormous commercial advantage over the Old World, because it was pest-free and disease-free.

The second was an extreme narrowing of the genetic base. In the centre of origin of sugarcane, there is a bewildering variety of different sugarcane clones. But, it seems, only *one* cultivated variety, one cultivar, was taken to the New World. It still exists and, in India, is called *Puri*. It is also known as *Yellow Egyptian* and, in Spain, it is called *Algarobena*. In the New World, it is called Creole, or *Cana Criolla*, which is Spanish for "native cane". The extraordinary thing about Creole was that it was the *only* clone of sugarcane present in the New World for more than 250 years.

This cultivation of a single clone, over a huge area of the tropical New World, for a period exceeding two centuries, constituted one of the most extreme monocultures ever recorded. It exceeded by far the monoculture of bananas (Chapter 19), and it was possible only because all the important pests and diseases of sugarcane had been left behind in the Old World.

Creole is a variety of *Saccharum barberi*, and it is a very tough cane, which can be grown almost anywhere in the tropics and subtropics. This toughness also helped the monoculture. Nevertheless, the New World was fortunate in its very narrow base of genetic material of sugarcane, just as Malaysia was fortunate in its narrow base of genetic material of rubber (Chapter 12). In each case, and largely by chance, these areas received some of the best material available, and they received it free from parasites.

Towards the end of the eighteenth century, the maritime nations of Europe had explored the world fairly thoroughly, and they were moving crop plants from continent to continent with quite reckless abandon. It was during this period that a noble cane was taken from the Far East to the New World and was found to have a

higher yield of sugar than the old Creole cane. This new cane is believed to have been collected by the French admiral Bougainville, after whom one of the Melanesian group of islands, and the ornamental plant *Bougainvillea*, are named. He collected this new cane when he circumnavigated the world in 1766-68.

Bougainville took this cane to the French island of Bourbon (now called Réunion), in the Indian Ocean, and the cane became known as "Bourbon" when it was later taken to Martinique, Guadeloupe and Haiti. The original name of this cane was "Otaheite" and Captain Bligh, famous because of the mutiny on his ship, the *Bounty*, also took it to the West Indies in 1793.

Because of its superior yield, Otaheite (or Bourbon) rapidly replaced Creole and, once again, the entire cane industry of the New World became dependent on a single cultivar. This was a very dangerous situation because, as more and more transfers of crop varieties were made around the world, so more and more pests and diseases began to be spread to places where they had never been seen before. Otaheite turned out to be a very susceptible cane variety. This created a very grave crop vulnerability which, as we have seen (Chapters 4 and 11) means that a crop of exotic origin is susceptible in the absence of its pests and diseases. When those re-encounter pests and diseases are introduced to the new area of cultivation, the susceptibility is revealed and vulnerability is converted from potential damage into actual damage.

In the French islands of the Indian Ocean, Otaheite failed suddenly in 1840 and had to be replaced with other, inferior varieties. This was about the time of the great Irish potato famine (Chapter 12) and no one in those days knew anything about plant diseases. Crop failures were attributed to such ill-defined things as evil fumes and miasmas. For this reason, we do not know what parasite of cane destroyed "Bourbon" in the French Indian Ocean islands.

In 1860, Otaheite failed in Brazil. Equally suddenly, it failed in Puerto Rico in 1872 and, one by one, in all the other West Indian islands between 1890 and 1895. The re-encounter parasites were beginning to catch up with the New World sugarcane industry. This was to have important economic effects. But it had important political effects also.

Towards the end of the eighteenth century, sugarcane began to have increasingly important political reverberations in Europe. The nations of Europe which had colonial ambitions were those which had an Atlantic seaboard and, hence, an ocean-going navy. These nations were Holland, France, Spain, Portugal, and the United Kingdom. They each had a turn of being “top nation” when it came to having command of the sea. As every schoolboy knows, Britain’s turn came last but it endured the longest. It was finally established with the destruction of the French navy in the battle of Trafalgar, in 1805, and it lasted until Britain was both bankrupted by World War II, and eclipsed by the two new superpowers.

Being the nation with command of the sea, Britain could impose a blockade on its enemies. North America was the only place in the entire world which still had coniferous trees large enough to make masts for the huge timber warships of that time. The primary purpose of the British blockade of Napoleon was to prevent him from getting new masts because, so long as he lacked them, he could not build warships. Once Napoleon's navy was destroyed at Trafalgar, the British strangle-hold on French sea-power became absolute, and the British could blockade continental Europe as they pleased. (It was only much later that ship builders learnt how to make masts out of many, smaller pieces of timber fitted tightly into a steel casing but, by then, the need for masts was giving way to steam).

As we saw in the discussion of sugar beet, one of the commodities the British blockaded was sugar from the West Indies. The shortage of sugar became acute in

continental Europe, and this encouraged Napoleon to promote the production of beet sugar, which has been competing with cane sugar ever since.

In those days, all the maritime nations of Europe owned West Indian islands which they valued mainly for their naval significance, and their sugar production. The public demand for sugar was so great that governments feared the public outcry that would be aroused against a war that denied the populace their sugar. And, in times of war, the sugar trade was often the first to be disrupted.

Sugarcane was a political crop for another reason. It is a horrible crop to work in. The leaves have sharp edges which lacerate the skin, and the cutters must wear long-sleeved shirts. Cutting cane is consequently one of the heaviest, most sultry, sweltering jobs in the world. Nowadays, can is cut mainly by machine but, in those days, the only labourers who could be made to cut cane were African slaves. And, at the beginning of the nineteenth century, there was a very powerful political movement for the abolition of slavery.

The first nation to abolish slavery was Denmark but, as this nation owned only a few slaves, in what are now the American Virgin Islands, this was a gesture rather than significant action. Britain prohibited the slave trade in 1807. After the Napoleonic wars, Britain was as wealthy, relatively speaking, as the United States was after World War II. In terms of international goodwill, Britain's equivalent of the Marshall Plan was to abolish slavery, and to pay compensation, in gold, to every slave owner, for every emancipated slave, throughout all the lands she controlled.

Having command of the sea, the British navy could also patrol the coasts of West Africa and, by *force majeure*, stop the slave trade. Slaves liberated from slave ships could not be returned to their own countries because they had been sold into slavery by their own people in the first place. So the British took them to an

uninhabited part of the coast called Sierra Leone which Britain, by then, had grabbed as a colony.

Sierra Leone has one of the very few natural harbours on the West African coast, and Britain wanted it because she was, above all, a maritime nation. A new town grew up around this harbour, populated by liberated slaves from all over West Africa. They called it Freetown. Later, it was to be made famous by Grahame Greene in his novel *The Heart of the Matter*, which dealt with a form of spiritual slavery. The French had a comparable colony for freed slaves in Gabon, and its town is called *Libreville*.

In 1888, a singular discovery was made simultaneously in Barbados and Java. The British scientists Harrison and Bovell, and the Dutch scientist Soltwedel, discovered that it was possible, after all, to grow sugarcane from true seeds. This meant that sugarcane breeding became a practical possibility for the first time. A wave of cane breeding followed, and this had such a dramatic effect on cane production that it has even been called the first "green revolution".

Cane breeding stations were set up in all the major cane growing countries. A convention developed in which a new cane variety was named with the initials of its breeding station followed by figures that identified the clone. Thus, all "Co" varieties come from Coimbatore in India, all "B" varieties from Barbados, all "H" varieties from Hawaii, and all "POJ" from the Dutch Proefstation Oost Java. Without the slightest doubt, the most famous new cane variety of all was POJ.2878. It was soon to be grown in just about every cane producing country of the world, and it became an ancestor of every modern cane variety, mainly because of its resistance to disease.

The durability of disease resistance in sugarcane is well established. For example, in the early part of the present century, a re-encounter virus disease, called mosaic, appeared in the sugarcane of South Africa. All the existing varieties were

highly susceptible, except one called “Uba”, which was of such poor quality that it was described as being more like a bamboo than a sugarcane. The South African sugar industry faced ruin. It was eventually saved by POJ.2878, and varieties bred from it, which are resistant to mosaic. This disease has never again been serious in that area.

A similar story can be told of every cane producing area when the mosaic virus first appeared. There have been occasional subsequent outbreaks of mosaic virus, but only because the disease was controlled so totally, that breeders sometimes forgot to test new varieties for resistance to it, and they inadvertently released a susceptible variety to farmers.

In 1936, in his presidential address to the American Phytopathological Society, G. H. Coons spoke about controlling plant diseases by breeding crops for disease resistance. In those days, it was considered essential to use single gene resistances, and gene-transfer breeding methods, leading, as we now know, to vertical resistance which is usually temporary in its effects. In those days also, scientists working in crops such as wheat, potatoes and beans, were already beginning think that *all* disease resistance was bound to fail sooner or later, because of new strains of the parasite.

Coons believed otherwise. In his presidential address, he described how the historic sugarcane industry of Louisiana was ruined during the years 1923-1927 due to three recently introduced diseases. These were mosaic, red rot and root rot, to which all the old cane varieties were highly susceptible.

When the old varieties were replaced with new ones, these diseases virtually disappeared, and the State average yield of sugar increased by fifty percent. Coons believed that this resistance was durable. And he was right. It has now endured for some eighty years, and no one seriously suggests that the resistance is going to break

down to new strains of these parasites. Perhaps the pedigree breeders of wheat, rice, potatoes, and beans, should take a more careful look at sugarcane.

It is safe to assume that all resistance to sugarcane pests and diseases is horizontal resistance (Chapter 2). In theory, this means that a sugarcane cultivar should last for ever. It should never have to be replaced because of a failed resistance. In practice, however, there are two situations in which the horizontal resistance of a cane cultivar can apparently fail, or can become inadequate.

As already mentioned, a new cane cultivar may not be tested carefully enough before being released to farmers. It might be very susceptible to, say, mosaic virus, but this susceptibility is not apparent because of faulty or inadequate testing. It is only later, when the new cultivar is established as a crop, that the susceptibility becomes apparent. It is then very easy, and very tempting, for the crop scientists to blame nature, and to claim that a vertical resistance has broken down, rather than to admit to their own carelessness.

The second kind of false failure of resistance occurs when a crop vulnerability is manifested. In the 1970s, two additional re-encounter sugarcane diseases finally reached the Caribbean, more than four hundred years after the crop itself had been introduced there. The first of these diseases was "smut" caused by a microscopic fungus called *Ustilago scitaminea*. This is a spectacular disease in which the entire shoot of the cane is transformed in to a smut "whip", up to six feet long and covered in black microscopic spores which are like a very fine soot. It has been estimated that one smut whip may produce as many as one hundred *trillion* spores.

The second disease was sugarcane rust, *Puccinia erianthi*, which is a close relative of the rusts that have caused so much trouble on wheat (Chapter 6). It produces rust red pustules on the leaves and, in a susceptible cultivar, the plant is killed because of the loss of leaf.

Throughout the Caribbean, there were sugarcane cultivars that were susceptible to one or other of these re-encounter diseases. These susceptible cultivars had to be replaced with resistant ones, and then the problem was not only solved, it was permanently solved.

However, the susceptibility was occasionally a very serious one, at least for a time. Cuba, for example, is the second largest sugarcane producer in the world (after Brazil), with an annual production of eleven million tons of extracted sugar. When rust appeared in this island, one third of the total cane crop was planted to a rust-susceptible cultivar and, because several years were required for its replacement, Cuba suffered some crippling losses in production.

At about this time, the sugarcane scientists in Barbados were anticipating the arrival of both smut and rust, because these diseases were already present in mainland South America. Barbados has its own cane breeding station, and it has a wealth of cultivars to choose from. The Barbados scientists decided to test as many of them as possible in South America, so that they would know in advance which cultivars were susceptible. The idea was to remove any susceptible cultivars from cultivation, as part of the routine replanting process, *before* the diseases appeared in the island. This is quite the best way of solving problems of crop vulnerability.

Barbados sent 1,600 cane cultivars to Guyana for testing. Each cultivar had to be tested twice, for susceptibility to each of the two diseases. Guyana is a very small, and very poor, country. It has few scientists, and those it does have are over-worked. The task that these scientists undertook was a heavy one, but they knew that their results would be of immense benefit, both to Barbados, and to the whole of the Caribbean. This was a magnificent example of international goodwill, and of the assistance that non-industrial countries can give to each other.

The results were impressive. When smut and rust finally arrived in Barbados, they caused no damage whatever.

Chapter Eighteen

Tobacco

History

When Columbus arrived in the New World in 1492, he saw many things which no European had ever seen before. But one of these novelties was astonishing beyond all others. This was the ingestion of a plant by means of *smoke*. To people of the Old World, this was a traveller's tale too fabulous to be believed. The plant, of course, was tobacco (*Nicotiana tobaccum*), and the material being ingested was an alkaloid called nicotine.

A special feature of nicotine is that it is destroyed by stomach acid when swallowed, and the only way it can be ingested is through the surface of other internal membranes. In practice, this means through the membranes of the lungs, by inhaling tobacco smoke, the membranes of the nasal passages, by snuff, or the membranes of the mouth, either by chewing tobacco, or by smoking tobacco which produces a smoke too strong to inhale, such as pipe tobacco, or a cigar.

Both the botanical genus, *Nicotiana*, and the alkaloid nicotine, were named after Jean Nicot, a French ambassador to Portugal, who sent tobacco seeds to Catherine de Médici, Queen Consort, and Regent of France, in Paris, in 1550. There was little difficulty in sending them because tobacco seeds are among the smallest known, with 300,000 seeds per ounce, and they are produced at a rate of up to one million per plant.

The name tobacco is derived from *tabaco*, the native word for the pipe constructed with reeds, or with tobacco leaf, like a crude cigar, that was smoked by

the “Indians” of the New World. This was known as “the pipe of peace”. It was seen by Columbus' men during his first landing in Cuba, being used by the elders who passed around a long cigar for all to smoke. Those original cigars were true pipes, like a short length of water pipe. The modern usage of tobacco pipe, with its bowl, stem, and mouth-piece, is an obvious linguistic corruption.

These tobacco-smoking people who met Columbus belonged to the Taino tribe of the Arawaks, who had migrated to the Greater Antilles from South America. The Taino were not as culturally advanced as the Aztecs of Mexico. But, unlike the earlier inhabitants of the area, who were hunter-gatherers, the Taino had a developed agriculture. They had houses built of logs, with thatched roofs, called *bohíos*, and they made pottery and baskets. They were also skilled at working stone and timber. Tragically, within a century of the arrival of the Spaniards, they were extinct, having been decimated by smallpox and measles. The survivors were either enslaved, or they ran away. Their social disruption was total, and starvation was then inevitable.

Domestication

The earliest archaeological record of tobacco comes from a bas-relief in a temple at Palenque, in Chiapas, Mexico, dated 432AD, showing a Mayan priest blowing smoke through a pipe. Another figure, on a pottery vessel, of a Maya smoking a roll of tobacco leaves, was found at Uaxactún, in Guatemala, and dates from the tenth century AD. Cave dwelling Pueblo Indians in Northern Arizona left loose tobacco, and pipe dottle, in a stratum dating from 650 AD, and traces of nicotine have been found in this ancient material.

In prehistoric times, about eight different species of tobacco were probably cultivated, but none of them are utilized today. Modern tobacco is a hybrid between two wild species which, however, have not been identified with any certainty. As

with many inter-specific hybrids, there was a doubling of the number of chromosomes to produce a tetraploid, and this made the hybrid fully fertile.

The hybridization was sufficiently ancient that no wild *Nicotiana tobacum* is known, although escapes from cultivation are common. A second species, *Nicotiana rustica*, is sometimes cultivated for commercial nicotine extraction, but it is of minor economic importance. It too is an inter-specific hybrid of uncertain parentage, with a doubled chromosome number, and it also does not occur wild.

Another indication of the antiquity of the domestication of tobacco is that, like non-shattering wheat (Chapter 6), maize (Chapter 7), and rice (Chapter 8), it does not shed its seeds. The seed capsule of cultivated tobacco remains tightly closed at maturity, and it must be broken open by people, if the seeds are to be released. This is a characteristic that is never found in the wild plants, which must obviously disperse their seeds if they are to survive. There is little doubt that the preservation of the closed capsule of cultivated tobacco, which could never survive in the wild, is the result of deliberate selection by indigenous Amerindians many centuries before the arrival of Europeans.

The part of the tobacco plant that is utilized is the leaf. A remarkable feature of tobacco leaves is their ability to smoulder. Once ignited, a dry tobacco leaf will usually maintain a red-hot edge which spreads until stopped by the larger leaf veins. With some smoking tobaccos, in which this characteristic is only poorly developed, the leaf is sprayed with a solution of potassium nitrate, to enhance the smouldering ability. This chemical, which is an oxidizing agent, is one of the constituents of gunpowder, and is otherwise known as saltpetre. It is what makes some of the cheaper brands of cigarette splutter and crackle as they burn.

Cultivation

The tobacco plant shows considerable ecological tolerance. It was originally a plant of the tropics and subtropics, but it is now cultivated in virtually every country of the world, and it is grown as far North as Canada and Sweden, and as far South as Australia. It will not tolerate freezing but, provided it has 90-120 days without frost, it will produce a crop. Unlike its botanical relative, the potato (Chapter 11), tobacco is not sensitive to day length.

Although the plant shows this environmental tolerance, the leaf quality does not and, indeed, the flavour and aroma can be drastically altered by only small differences in environment. The grading and classification of tobacco leaf for market is accordingly based on both the parent cultivar, and the area in which it was grown. Differences in tobacco quality have nuances not nearly as delicate as those of wine (Chapter 20), but possibly as delicate as those of tea (Chapter 13), and coffee (Chapter 14).

Tobacco seeds are so small that it is impossible to sow them directly into the field. They must first be germinated in a seedbed, and allowed to develop into reasonably tough seedlings. However, one level teaspoonful of tobacco seed is enough to sow a seedbed measuring thirty square yards, and the seeds must be mixed with sand or ash to obtain an even distribution in the seedbed. Alternatively, they may be suspended in water, and sprayed on to the seedbed with a watering can that has a very fine rose.

The seedbed soil must be pasteurized, either with injected steam from a mobile boiler, or with soil sterilizing chemicals. The seedbeds are kept shaded with special covers which are gradually removed as the seedlings grow. Some 40-60 days after sowing, the seedlings are ready to be transplanted in the field.

Pesticides

There are special problems when it comes to spraying tobacco crops with insecticides and fungicides. For example, one of the ways to prevent a disease called powdery mildew is to dust the tobacco with flowers of sulphur, or to spray it with an emulsion of colloidal sulphur. But, although sulphur is harmless in itself, and much liked by farmers for this reason, it burns to produce sulphur dioxide, which is highly toxic. Tobacco is the one crop on which it cannot be used. Indeed, tobacco is the one crop on which no insecticides or fungicides whatever can be used, unless in the form of a soil application, or a seed treatment. Tobacco sprayed with chemical pesticides is likely to be toxic, in the way that sprayed cannabis (Chapter 21) is toxic.

This means that disease resistance is very important in tobacco. So are indirect methods of pest and disease control. This is well illustrated by a recent story from Cuba. In order to increase the amount of tobacco available for export, Fidel Castro decided to ration cigarettes. There was an almost immediate black market in tobacco, and many people took to growing a few plants, either for sale, or to augment their own rations.

These private tobacco plants were illegal because they were grown during the closed season for tobacco. When there was continuous cultivation, an immediate and damaging epidemic of a disease called blue mould developed. The disease was spectacular, and ninety percent of the Cuban tobacco crop was destroyed. As soon as the reason for the epidemic was understood, the cigarette rationing was abolished, the private tobacco growing stopped, and the closed season was re-established. There were then no more epidemics of blue mould.

Blue mould is a disease similar to blight of potatoes (Chapter 11) and downy mildew of wine (Chapter 20), and it is caused by a microscopic fungus called *Peronospora tabacina* which is a native of Australia. It is thus a new encounter

disease (Chapter 5). It appeared in Europe for the first time in 1959. There is a story, possibly apocryphal, that during a conference of European scientists convened to discuss this problem, the British delegates admitted that some of them had illicitly imported this fungus for research, and that it had apparently escaped accidentally from their laboratory. They could easily have kept this information secret but, in the interests of scientific truth, they felt compelled to admit their error.

The other delegates were no doubt furious with the British scientists for the problems they had caused. But then the Dutch delegation announced that they too had made illicit imports of this fungus, and that it might possibly have escaped from the Dutch laboratories, rather than the British.

There is nothing a scientist likes less than to admit publicly to having been really stupid. But, in science, truth takes precedence over all other considerations. And these scientists, who sacrificed their pride, and risked the esteem of their colleagues, in the interests of truth, were perhaps the finest scientists of them all.

Harvesting

There are two methods of harvesting tobacco. With both methods, the plants are 'topped' to prevent flowering. If the harvest is for flue-cured tobacco, described in a moment, the lowest and oldest leaves of the plant are collected, two to four leaves at a time, in a series of harvests. Air-cured and fire-cured tobacco, as well as cigar filler tobacco, is usually harvested by cutting off the entire plant at ground level, some 40-55 days after topping.

Curing

There are four basic ways of curing tobacco. Air-cured, or barn-cured, tobacco is hung in a wooden barn and allowed to dry out over a period of 6-8 weeks. This

usually produces a dark and strong tobacco used, typically, in French and Latin American cigarettes, for pipe tobacco, and for cigar filler. Fire-cured tobacco differs in that small open fires are burned inside the barn to accelerate the curing process. This kind of tobacco, which is also dark and strong, has a distinctive smoked aroma. This curing process requires 3-4 weeks.

Flue-cured tobacco is processed in a heated barn in which the smoke of the fires is confined inside pipes, or flues. The tobacco then has no aroma of smoke. The great advantage of flue curing is that it requires only 4-8 days. It results in a light-coloured, golden, mild tobacco, used mainly in cigarettes.

Each type of curing involves a different kind of tobacco. Another type of smoking tobacco is Turkish or oriental, and it comes from an entirely different group of tobacco varieties, which are grown mainly in the Eastern Mediterranean. They are smaller plants with a very different aroma and flavour. Turkish tobacco is also cured differently, mainly by sun drying, to produce a dark and strong tobacco with a very distinctive aroma.

There are marked national preferences in the taste of cigarettes. The British like a flue-cured Virginian without any blending or flavours. Americans like a blended cigarette, consisting mainly of flue-cured tobacco but usually with a proportion of Turkish tobacco and, possibly, some air cured and fire cured tobaccos as well. American cigarettes are sometimes flavoured with molasses and other substances. The extreme of flavouring is with the clove cigarettes of Indonesia (Chapter 10). French cigarettes are made entirely with a dark, air cured, tobacco, sometimes blended with fire cured tobacco. So are most of the cigarettes of Latin America. Turkish and Egyptian cigarettes contain much higher proportions of Turkish tobacco.

Tobacco leaf is packed after curing, typically in hessian (burlap, or sackcloth) bales, and it is usually left to mature, in the bales, for one or two years before it is manufactured into smoking materials.

Pipes

As we have seen, the Taino Indians smoked their tobacco in a crude pipe made of reeds or bamboo, or they made a clumsy form of cigar from rolled tobacco leaf. It was only later, in Europe, that tobacco was smoked in a pipe manufactured specially for the purpose.

For many men, the tobacco pipe became an absorbing interest, even an obsession. The long process of filling it, and keeping it burning satisfactorily, is a wonderful occupation for nervous fingers. Pipe smoking has even been compared to the worry beads of Balkan cultures. It has also been suggested that fiddling with a pipe is the equivalent of the displacement activity of animals meeting at a territorial boundary.

Many men with the collecting instinct would collect tobacco pipes, rather than postage stamps or coins, often collecting many more than they could ever use. And tobacco pipes were often very expensive. Originally, European tobacco pipes were made from a white clay which came to be known as pipe clay. This term was even used when a whitewash, made of this clay, and also known by its Spanish name of *blanco*, was painted on to military equipment to make it smart. The advantage of clay pipes was their cheapness, but they were also fragile and would break easily.

The old mass graves of victims of the Great Plague in London can often be identified by the fragments of clay pipes among the skeletons. This was because tobacco was believed to provide protection against the plague, and sextons would

smoke it continuously, during their work of burying people who had died of this disease. Samuel Pepys used to chew tobacco during the Great Plague, in London, in 1665, for this reason. Those were the days when school boys were beaten for *not* smoking.

Clay pipes with long stems were known as church wardens, and were popular because the long stem cooled the smoke before it reached the mouth. In the United States, the cheapest pipe was the corncob pipe, which was usually home-made. General Douglas MacArthur made his corncob pipe nearly as famous as Churchill's cigar.

Another popular, but expensive, material for pipes is meerschaum, which is a German name meaning "sea foam", so called because it floats, and used to found floating in the Black Sea. There is even a popular myth that meerschaum is fossilized sea foam which, of course, is nonsense. Meerschaum is a mineral whose technical name is sepiolite. It consists of a relatively rare form of clay called a fibrous clay, and it is a breakdown product of serpentine. The chief commercial deposits of meerschaum used to be in Turkey but these are becoming exhausted and the main source of supply is now from Amboseli, in Tanzania.

Meerschaum is soft when first extracted, but it hardens on exposure to the air. This makes it easy to carve, and meerschaum pipes are often beautifully sculpted. The most expensive mouthpieces were made of real amber, but this material is rare and mouthpieces were more often made of vulcanite (Chapter 12). A markedly conical pipe, known as the Sherlock Holmes, is made from the U-shaped neck of a specially cultivated bottle gourd, and it is lined with meerschaum.

The most common pipe these days is the briar pipe, made from the burls of white heath, a Mediterranean species of heather, *Erica arborea*. This plant is closely related to the white heather of Scotland, and is in the same botanical family, the

Ericaceae, as the cranberry, huckleberry and blueberry of North America. The bowl of a briar pipe takes a deep polish and is usually beautifully grained.

A final comment on tobacco pipes concerns the hookah, still widely used in the countries of the Middle East. The essential feature of a hookah is that the hot smoke is bubbled through water and cooled. The hookah is usually quite a large apparatus, with the burning bowl at the top and the water container below. One or more smokers are linked to it with flexible pipes, each with a mouthpiece. The water in the hookah is often scented in order to add a perfume to the tobacco smoke.

Cigars

It is thought that the Spanish word *cigarro*, from which the words cigar and cigarette are derived, comes from the Mayan word *sik'ar*, which describes tobacco smoking. Modern cigars consist of a core of cut tobacco filler, rolled in a 'binder' leaf, and all enclosed in a 'wrapper' leaf. The wrapper leaf is made from the highest quality, and most expensive, leaf of all. It is specially cultivated under shade to produce a leaf that is strong and elastic, with a uniform colour and silky texture. The wrapper leaf must have an excellent aroma, and good burning characteristics. It must also be free of holes, which are often caused by insects, otherwise the cigar is not airtight, and it will not draw.

Cigars are traditionally packed in boxes made from an aromatic timber obtained from the so-called West Indian cedar (*Cedrela odorata*) which, in fact, is not a cedar at all, but a member of the mahogany family (*Meliaceae*). It is likely that this wood was first used as an insect repellent. However, the aroma of this wood is now considered so important to a good quality cigar, that slivers of it are enclosed in the aluminum tubes that are used as modern packing for cigars.

Most categories of cigar are described in terms of a standard called the *corona*. This is open at the far end, and rounded, and closed, at the top, which is the end that is put to the mouth. Such closed cigars have to be pierced, and cigar smokers usually carry a special gadget for this purpose, often made expensively of gold. Less elegant cigar smokers use their teeth, and spit out the severed end. The corona is of uniform width, and is about five and a half inches long.

Smaller cigars of similar shape are known as the *petit corona*, or *corona chica*, the *très petit corona* and the half corona. *Lonsdale* is similar to a corona but longer, while *Londres* is also similar but shorter. *Ideales* is a tapered cigar which is lit at the thin end. Other types include the *panatella*, open at both ends, and its variants, as well as the *cheroot*, which is like a panatella but thicker and shorter.

The finest cigars are made in Cuba, following a tradition that can be traced way back to before the first arrival of Columbus in 1492. They are known as Havana cigars, after the capital of the country. Unfortunately, the United States ban on trade with Cuba, combined with modern apprehensions about the dangers of tobacco smoking, have largely killed this ancient industry, and the skills that go with it, probably beyond any possibility of recovery.

Cigarettes

Traditionally, tobacco smoking was exclusively a man's occupation, and only the lowest class of women would stoop to the use of a pipe or cigar. During the nineteenth century, it was bad manners for a gentleman to smoke in the presence of ladies, because non-smokers do not like the smell of tobacco smoke. Most aristocratic houses, and high class hotels, had a special room, called the smoking room, set aside for this purpose. And, at a very early date, railway waiting rooms, and carriage compartments, were designated as either “smoking” or “non-smoking”.

This tradition concerning the exclusively masculine use of pipes and cigars is still a strong one but, nevertheless, feminine equality in smoking became firmly established during World War I. As with many other feminine equalities, such as universal suffrage, this one came when women gave practical demonstrations of their equality, mainly by replacing men in the armaments factories. The social acceptance of feminine smoking was greatly facilitated by the popularity of a relatively new, elegant, and refined method of smoking called the cigarette.

The term cigarette is French, and it means “little cigar”. Originally, cigarettes were made by beggars in Spain who utilized discarded cigar butts by shredding them, and rolling the tobacco in a scrap of paper. Later, cigarettes began to be specially manufactured. Their use and popularity increased slowly throughout the nineteenth century, as special tobaccos were developed for cigarette manufacture.

The main reason for the popularity of cigarettes was that, unlike pipes and cigars, they produced a mild smoke that could be deeply inhaled into the lungs. The inhaling of tobacco smoke greatly increases the drug effects of the nicotine, including its addictiveness. There can be little doubt that the development of mild cigarette tobaccos transformed the tobacco industry, in much the same way that the pneumatic tire transformed the rubber industry (Chapter 12).

The development of cigarettes also transformed society, and it did so in every country, and culture, of the world. First, the use of tobacco increased dramatically until world consumption reached ten *billion* pounds annually in the mid-1960s. That was more than two pounds of tobacco each year for every man woman and child in the world.

Human Health

We must recognize that the inhaling of tobacco smoke is an immensely satisfying experience. This incredible quantity of tobacco must have made an enormous contribution to human happiness, most specially to the happiness of the poor, both the poor in money, and the poor in spirit.

The second impact on society was the effect of tobacco on human health. At the turn of this century, there were no antibiotics, and few vaccines, and people were dying routinely from infectious diseases. The deleterious effects of tobacco were too minor, in comparison, to be considered important. So too, for that matter, were the long-term effects of dust in miners' lungs, motor car accidents, the dangers of asbestos, and other health hazards which are now prominent only because there so few ways left to die.

There is little doubt that tobacco contributes significantly to the incidence of lung cancer, as well as certain other diseases such as emphysema, chronic bronchitis, and coronary diseases. Pipe and cigar smoking also increase the rates of cancer of the mouth, jaw, and lips. In most industrial countries, cigarette advertising is now banned, and cigarette packets carry a health hazard warning.

Equally unattractive, however, are the members of a loose anti-smoking coalition who seem to believe they have a divine right to control people who wish to smoke. Many of them positively dislike the smell of tobacco and they are entirely reasonable in their demands for smoke-free areas in public places. But the extremists among them seem to want a total ban on smoking. They have a reforming zeal, and a proselytizing fervour, that verge on the fanatical. And they are prepared to trample ruthlessly on the rights of others. They seem to forget that smokers have rights too, and that smoking in moderation is not nearly as dangerous as many people make out. Perhaps we should return to the Victorian idea of smoking rooms in public buildings.

Mechanisation

The first machine for making cigarettes was invented by James A. Bonsack, in the United States, in 1880, and all subsequent machines use the same basic principles. An endless "cord" of finely shredded tobacco is laid on a ribbon of cigarette paper which is drawn through a funnel that rolls the paper into a tube around the tobacco. The edges of the paper are glued together and the roll is cut into appropriate lengths with a rotating knife.

The manufacture of filter cigarettes is slightly more complicated as the filters must be inserted into the cord of tobacco. This is done in such a way that the knife cuts a double-length filter, and a double length cork tip, into two cigarette ends. At the next rotation, the knife cuts through tobacco. Alternating cigarettes are sent to two different bins to ensure their uniform alignment, with all the filter ends pointing in the same direction.

Other Uses

Three other uses for tobacco should be described. The first of these is snuff, which is a dried, powdered tobacco that is sucked into the nostrils. Snuff taking used to be immensely fashionable, and snuff boxes became almost as popular among men as wrist watches are today. Like wrist watches, snuff boxes were supplied by jewelers, and were often made of precious metals, and decorated with precious stones. With the development of cigarettes, however, snuff and snuff boxes disappeared entirely.

Second, is the use of chewing tobacco, which used to be common in the United States. A wad of tobacco would be kept in the cheek, and one of its effects was to promote salivation. The tobacco chewer has a constant need to spit, and this is why

spittoons used to be such a common article of furniture in bars and public places. For the same reason, bars often had sawdust spread on the floor. Tobacco chewing was a disgusting habit that richly deserved to be abandoned. It was always considered a *macho* thing to do and, for this reason, it was popular among cowboys and baseball players. It is a curious feature of American baseball that it is every bit as conservative, and as resistant to change, as English cricket. This is possibly the reason why baseball players wear such old-fashioned clothing, and are now the only Americans left who still chew tobacco.

The final use for tobacco is an industrial one involving the extraction of nicotine. *Nicotiana rustica*, which has a much higher nicotine content, is cultivated for this purpose. The nicotine was used mainly as a horticultural insecticide because it is toxic to insects but harmless to plants. However, this demand largely disappeared with the development of synthetic insecticides.

Nicotine is also used in the pharmaceutical industry. A relatively new use for extracted nicotine is in the manufacture of nicotine chewing gum, which is used as an aid to smokers who wish to stop the habit.

Taxes

In all countries of the world, tobacco has always been an excellent source of revenue for governments. More than half the price of cigarettes is usually government tax. Many governments, and specially those with the Napoleonic code, even owned tobacco monopolies, and the purchase of cigarettes then involved dealing with government officials, who were often just as bureaucratic as post office clerks.

In Britain, the waste tobacco which accumulates in cigarette factories is known as tobacco “dust”. It is too finely divided to be of any use, and it is usually sold very cheaply to pharmaceutical companies for nicotine extraction. By offering a slightly

higher price, a very bright clerk is reputed to have bought up tobacco dust from all over Britain, until he had a large warehouse full of the stuff. He then went to the Customs and Excise people and announced that he was going to export all this tobacco, on which duty had been paid, and that he was claiming a refund of this duty. He put the tobacco dust into barges, and dumped it in the sea, outside the three mile limit, and the Customs and Excise was compelled to pay him a fortune in tax refunds.

Infernal Machines

Tobacco smoking, and particularly pipe smoking, required frequent ignition of the tobacco. The original method of making fire, by striking a flint in a tinder box, was far too clumsy for this purpose. Early pipe smokers tended to use a burning splint, or shaving of wood, to transfer fire from either a candle, or a household fire, to their tobacco. There can be little doubt that the habit of tobacco smoking did much to promote the development of matches, which are no more than self-igniting splinters of wood.

The first friction match was made by François Derosne in Paris in 1816. Samuel Jones invented his “Promethean” match in London in 1828. This complicated and dangerous match consisted of a small glass capsule containing acid, and coated with a combustible substance. This was wrapped in paper and the match was ignited by breaking the capsule, usually with one’s teeth.

In 1831, a Frenchman, Charles Sauria, started using yellow phosphorus, and matches made with this chemical soon dominated the market. They were popular because of their reliability, and their keeping qualities in damp weather. However, yellow phosphorus is poisonous, and workers in match factories would develop phosphorus toxicity symptoms known as “phossy jaw”. Yellow phosphorus matches were eventually banned throughout the world.

In 1855, in Sweden, J.E. Lundström patented the safety match. This employed red phosphorus, which is not poisonous, and which is not liable to ignite spontaneously, as would the older matches made with yellow phosphorus. Lundström ensured safety by separating the igniting materials between the match head and the striking surface. This is the basis of all modern matches, although non-safety matches, which can be struck on any rough surface, including the seat of a cowboy's pants, remain popular. These are made with phosphorus sesquisulphide in the heads.

Few further developments have occurred in match manufacture but the impetus of smoking did produce the gadget known as the lighter. Traditionally fueled with gasoline, the cigarette lighter would ignite by means of a spark produced by friction on a synthetic "flint". Probably the most famous lighter of all was the American "Zippo". After World War II, propane gas lighters were introduced. These were superior to the older gasoline, or petrol, lighters which tainted the tobacco. Propane lighters could also be ignited with a very low powered electric spark produced either by the piezo-electric effect, or from a small battery inside the lighter.

Accessories

Other manufactured articles invented exclusively for tobacco smoking are the ashtray, the cigarette case, the cigarette holder, and the pipe cleaner. Ashtrays have been designed in every conceivable shape and form, and many were the epitome of bad taste. Ashtrays for use in public bars and restaurants also became a favourite place for advertisements, usually promoting drinks or cigarettes. This kind of ashtray would be given away by the advertiser and, typically, they were very large, both to emphasize the advertisement, and to prevent them being slipped casually into the pocket.

For a time, cigarette cases replaced snuff boxes as a form of jewellery, and they were often made of precious metals. They were also a convenient gift, and were a suitable article for special presentations. For this reason, they were often engraved with a name, message and date. As Oscar Wilde commented, it was bad manners to read a private cigarette case.

Cigarette holders were designed primarily to avoid tobacco stains on the fingers. Some of them were also quite long, in order to cool the hot smoke, and others contained filters. However, with the increasing popularity of filter cigarettes, holders went out of fashion. Pipe cleaners were a curious invention, made of a twist of wire and cotton, and used for cleaning the stem of a pipe. The brown mess that would be removed was quite disgusting, and this has possibly done more to discourage pipe smoking than any other factor.

Scientific considerations

Finally, mention should be made of the scientific importance of the tobacco plant. For a variety of reasons, it is an ideal plant for fundamental scientific research, and it has attracted far more scientific attention than is warranted by its economic or social importance. Three examples are of interest.

Protoplast fusion is a technique of genetic manipulation that was first used with tobacco. It is well known that all plants and animals are constructed of microscopic cells, which are the basic units of life. Plant cells consist of the living contents of the cell, called the protoplast, and a protective shell, called the cell wall, which is made of cellulose, the substance of cotton (Chapter 16). Research on tobacco cells showed that it is possible to dissolve away the cellulose cell wall with an enzyme, and expose the naked protoplast without killing it.

In this condition, the protoplast is extremely delicate and vulnerable and, if it survives at all, it soon grows a new cell wall. Before that happens, it is possible to bring two naked protoplasts together in such a way that they fuse into a single protoplast. The two protoplasts that fuse can come from different species of plant and, with this technique, it is possible to produce plant hybrids that cannot be produced in any other way.

The second example concerns doubled monoploids. Every plant possesses two sets of chromosomes, or bundles of genetic code, with one set coming from the male parent, and the other from the female parent. Such plants are called *diploids*. It is possible to remove the anther, which is the male, pollen-producing organ of a plant, and to culture it in such a way that it produces a new, and very small plant, called a plantlet, that has only *one* set of chromosomes. Such a plant is called a *monoploid*, and it is sterile.

Using an alkaloid called colchicine, it is possible to double the number of chromosomes in a monoploid to produce a diploid of a very special kind called a "doubled monoploid". A doubled monoploid is fertile, and it has two sets of chromosomes which are identical. In practice, this means that a doubled monoploid can be reproduced by seed and its progeny are then the most perfect pure line that it is possible to obtain. In other words, the line breeds absolutely true to type, without any variation whatever.

This discovery has led to the possibility of an entirely new kind of plant breeding. It is theoretically possible to produce many thousands of doubled monoploids each breeding season. Each is genetically different from all the others. They can be screened, and the best can become new cultivars immediately.

With traditional plant breeding, the first step is to screen a variable population, and the selected individuals are then self-pollinated for about six generations to

produce pure lines. This takes time. With the doubled monoploid method, the procedure is reversed. The first step is to produce very large numbers of different doubled monoploids, and these are then screened. The final selections need no further work. They are ready for immediate use. This is a kind of "instant" plant breeding which is much faster than the traditional method. However, its feasibility varies with different species of crop.

Finally, for an exercise in genetic engineering, tobacco was used to demonstrate that a gene can be transferred from an animal to a plant. The animal was an insect, a firefly, and the gene was the one that controls the firefly's ability to produce light. When the gene was successfully transferred to tobacco, the plant glowed, even if very dimly, in the dark.

Chapter Nineteen

Banana

Ancient Domestication

The American biogeographer, C.O. Sauer, has postulated that some of the most ancient plant domestication occurred in the area of tropical Southeast Asia. He argues that many thousands of years of domestication are necessary to produce the characteristics typical of the older crops of this area. The main feature of many of them is that they can no longer be propagated by true seed. This is because domestication has changed the plant so much that the true seeds generally revert to the wild type, producing seedlings so primitive that they are useless for cultivation. Sometimes the ability to produce true seed has been lost entirely. All such cultivars have become totally dependent on people for their propagation and survival.

Another feature of ancient domestication is a wealth of different cultivars. In ancient crops such as these, new cultivars are difficult to produce because true seedlings are both rare and of low quality. The rate of development of new cultivars is then slow, because there are very few chance seedlings, and very few of them produce a plant worth preserving. Under these circumstances, a wealth of different cultivars indicates a very long period of agricultural history.

Because these plants either do not set seed, or because their seedlings revert so completely, they must be propagated vegetatively. Each cultivar is then a clone. All the individuals within a clone are genetically identical, apart from a rare mutant, or

‘sport’. A special feature about clones is the way in which virus diseases accumulate within them.

Virus diseases are not normally transmitted by true seed, but they are transmitted freely by vegetative propagation. If a clone is of very ancient domestication, therefore, it follows that it must be highly resistant to every virus disease within its area of origin. Otherwise, its yields would have declined, and it would have died out, long ago.

It should also be remembered that ancient people knew little about plant pests and diseases, or how to control them. There were no chemical pesticides in those days. It follows that a clone of ancient domestication is resistant not only to all the virus diseases, but to all the other local pests and diseases as well. Any clone which was susceptible to even one species of parasite, so that it yielded poorly, or not all, would become extinct quite quickly. After all, it was totally dependent on people to propagate it, and if the people concerned did not like it, that would be the end of it. There was no way in which a susceptible clone could have survived until the present. Ancient people did not know about museums, or gene banks.

Another feature of ancient domestication is the extent to which the domesticated plant is modified. With a very old domestication, the plant is usually changed so much that modern scientists may have considerable difficulty in recognising its wild progenitors. Such profound changes require many millennia of unconscious selection by culturally nascent people.

Finally, ancient domestication is often characterised by the complete disappearance of the wild progenitors. This happens because the wild types were exploited to extinction by hunter-gatherers, and only the superior, domesticated types were preserved by farmers.

The characteristics of ancient plant domestication are thus (i) a reduction, or complete loss, of seed propagation, (ii) a wide variety of clones in the area of origin, (iii) high levels of resistance to all the local pests and diseases, especially viruses, in the area of origin, (iv) genetic modification to the point that the wild progenitors are difficult to recognise, and (v) the complete disappearance of the wild progenitors.

Plant species in Southeast Asia which come into this category of very ancient domestication, include banana, sugarcane (Chapter 17), and taro (Chapter 2). Coconut is also in this category even though it is propagated exclusively by seed. This is because no one has ever succeeded in propagating a coconut vegetatively. An excellent example from West Africa is the yam (Chapter 3). Species from the temperate regions of Asia include apples and pears. Species from the Middle East and Mediterranean areas include olives, grapes (Chapter 20), figs, and the date palm. Examples from the New World are rare, possibly because fewer people have been practising agriculture, for less time, in that area. But cassava, chillies, and pineapple possess many of these characteristics of ancient domestication.

The Plant

This chapter is about one of these ancient domestications, the banana. Its name derives from the Spanish and Portuguese who, in their turn, adopted the native name used in the Congo, where there is even a town called Banana, on the Atlantic coast. However, the centre of origin of the plant is the Malaysia-Thailand area. Its domestication is ancient. It cannot set seed. Hundreds of different clones are known. It is highly resistant to all its local pests and diseases. It has been considerably modified, and its wild progenitors are difficult to recognise. And, contrary to general belief, it is not a tree.

Botanically, a herb is any flowering plant that does not have woody tissues. This means that herbs are usually small, because only woody plants have tough stems that can support the weight of shrubs and trees. People often talk of the banana 'tree', because the plant is considerably taller than a man. But, in fact, the banana is a herb. Indeed, it is the largest known herb. It has a tall, thick 'trunk' which, in fact, is a pseudostem formed by leaf bases wrapped around each other. The flower bud is formed underground, in the true stem, and it is thrust upwards through the pseudostem by an elongation of the underground stem, which does not have any woody tissues.

The banana is one of the toughest of plants. It is not physically tough. Indeed, being a herb, it is easy to tear its leaves or cut right through the pseudostem with one slash of a cutlass. The toughness of the banana is an evolutionary toughness, and it is the ability to survive as clones. Crops that are propagated vegetatively are notoriously vulnerable to pests and diseases. Many clones die out quite quickly for this reason. But clones of banana have survived for hundreds, probably thousands, of years.

There are several kinds of banana. The true banana, as sold in supermarkets in temperate countries, is a seedless fruit that is eaten raw and ripe. It is sweet, and rich in calories, and in vitamins A and C. Plantains, on the other hand, are eaten cooked and unripe. They are starchy bananas, and they are an important food crop in the tropics. But plantains do not reach the markets of the temperate world. Confusingly, the bananas of international trade are called plantains in the temperate countries where they are sold. This word "plantain" thus has two totally opposed meanings, depending on the area where it is used.

A third kind of banana is called *abaca* and is cultivated mainly in the Philippines. This is not a food crop but an industrial crop, and it is cultivated for its fibres which are among the longest and strongest plant fibres known. The fibre is

called Manila hemp and, before the invention of nylon, it was in great demand for making ropes for shipping, and for fishing nets. In addition to being strong, Manila hemp is highly resistant to both fresh and sea water. However, once nylon rope and nets became available, the market for Manila hemp largely disappeared. This was yet another example of an agricultural industry succumbing to competition from the chemical industry.

A fourth kind of banana is called *ensete* (pronounced *en-setty*) and it is cultivated exclusively in Ethiopia. The fruit is not edible, and the crop is grown principally for its large underground stem, which is rich in starch, and is cooked in a manner similar to yams. Its fibres are also utilised.

A fifth kind of banana is known as the Pacific or *Fe'i* banana, and occurs in the islands of the South Pacific. It has fruit which are edible, after cooking, and its most obvious difference from ordinary bananas is that the fruiting stem points upwards, instead of hanging downwards. This banana probably represents an entirely separate domestication, in a different area, and from a different species of wild progenitor.

Some of the more distant relatives of banana are also of interest. One is the so-called ‘traveller's tree’ (*Ravenala madagascariensis*) which, as its name indicates, is a native of Madagascar, and which stores water in the base of its leaves. When these are cut open, good water, which is fit to drink, pours out, and can be utilised by thirsty travellers. It is a beautiful plant, with a huge fan of banana-like leaves. It also evolved to survive in the lateritic soils of Madagascar, which are some of the least fertile soils in the world.

Other relatives are species of *Strelitzia* and *Heliconia*. The former are indigenous in Southern Africa, and the latter are native to Latin America, and both are now popular ornamentals. *Strelitzia* is known as the bird of paradise flower, and *Heliconia* has a special agricultural significance, as we shall see shortly.

Dispersal

The edible banana was taken to Africa in prehistoric times, undoubtedly by the same seafaring Austronesians who took cinnamon across the Indian Ocean for the Roman spice trade (Chapter 10). In Uganda, there are legends about bananas, similar to the ancient Greek legends concerning olives being a gift from the godess *Athena*. Ugandan folklore maintains that the founder of the Baganda people, King Kintu, brought the first banana plant to his people, and that all the banana plants of Africa are derived from it. There is also genetic evidence indicating that the bananas of Africa are a distinct sub-population that spread from the East coast to the West coast, probably via the River Congo.

At about the same time, bananas were also taken to all the tropical islands of the Western Pacific but there is no evidence for this crop having reached the Americas before the arrival of Columbus. Alexander the Great saw bananas when he conquered India, and the fruit is mentioned in ancient Greek, Latin, and Arabic writings. The Portuguese found bananas in West Africa, in the fifteenth century, and took them to the Canary Islands.

Columbus used the Canary Islands as a replenishment base on all four of his journeys to America, and these islands subsequently became an invaluable staging post in the Spanish commerce with the New World. At least one clone of bananas is known to have been taken to Hispaniola (Haiti) in 1516, some twelve years after Columbus died.

Cultivation

In spite of being highly resistant to all its parasites, a clonal crop such as banana will still thrive more vigorously if it is moved to a new area, and its parasites

are left behind. It seems that this happened with bananas, as it did with coffee and sugarcane (Chapters 14 & 17), in the New World, and with rubber and cocoa (Chapters 12 & 15), in the Old World. In any event, the New World became the centre of commercial production of bananas, and they are produced there on a scale that does not appear to be possible in the Old World. The consumption of bananas in North America and Europe combined is more than five hundred million fruits *each week*. This, it will be observed, is the consumption of a tropical crop by temperate people.

The total acreage of bananas in Africa is considerably greater than the New World acreage, but with a difference. Bananas in Africa are a household crop, grown in small plots to feed individual households, but not grown for sale. There are millions of small, subsistence farms in Africa, and most of them have a household plot of banana. In some areas of Africa, such as parts of Uganda, bananas are even the staple food.

The huge plantations of banana, so typical of the New World, do not appear to be feasible in Africa, although a few plantations, producing for export, do exist in West Africa, and in Somalia. Australia and South Africa both have commercial production of bananas to supply their own domestic markets, but neither country exports bananas, possibly because of their great distance from suitable markets.

Most of the bananas of Africa, and of tropical subsistence farmers generally, consist of a wide range of varieties that are quite different from those of commercial production. Many of them are starchy bananas, that are eaten unripe and cooked, and which may also be brewed for beer. The many subsistence varieties of banana which are eaten raw and ripe usually have small fruit which are often green, or even red, when mature.

One of the agricultural advantages of the banana is that, once the crop is established, some 10-15 months after planting, it produces fruit continuously. Unlike most other fruits, it is not a seasonal crop. Each pseudostem of banana produces a 'stem' of fruit consisting of five to fifteen 'hands' which are the bunches of commerce. Each bunch consists of five to twenty 'fingers', the actual fruits. When the fruiting stem is removed, the pseudostem dies but it is replaced by several 'suckers', or new pseudostems, that have emerged from below ground.

One 'stem' of commercial fruit may weigh as much as 150 pounds, requiring two men to cut it down, and one acre will produce up to three hundred 'stems' per year, amounting to about twenty tons of fruit. The annual production of bananas for export is more than five million tons. A considerably larger quantity is produced for home consumption throughout the tropics, and this subsistence production can only be estimated but it may be as high as fifteen million tons annually.

In Western countries, the favourite metaphor for people being crowded is to compare them with sardines in a can. In tropical countries, canned sardines are largely unknown, and the metaphor for crowding is a comparison with bananas in a bunch. Hence the phrase 'banana bus', in which there are as many passengers as can force themselves inside, cling outside, or climb on the roof.

Banana Republics

In 1872, an American railway entrepreneur, M.C. Keith, began building a railway in Costa Rica and, along the route of his railway, he acquired land to grow bananas. In 1884, he signed a contract with the Costa Rican government to fund the national debt, and to extend his railway. In return, he was given nearly one million acres of virgin land, free of tax for twenty years, and he was guaranteed full rights to his railroad track. In 1899, he founded a new company for the purpose of growing

bananas on his land concession and, incidentally, providing freight for his railway. He called it the United Fruit Company.

The United Fruit Company quickly established itself, and soon became the dominant financial force in much of Central America. It expanded into various countries of the Caribbean. It built new railroads, established new banana plantations, and acquired a fleet of ships for transporting the bananas to North America and Europe. As quite minor sidelines, the company also produced sugar, cocoa, abaca, quinine, essential oils, rubber, and various tropical woods. It operated mainly in Honduras, Costa Rica, Guatemala, Panama, Ecuador, Colombia, Cuba, and Jamaica. For a time, many of these countries became so dependent on the company that they were known as 'Banana Republics'.

The United Fruit Company acquired so much economic power that it inevitably acquired political power as well. The penalties of power are to be hated and reviled. In Spanish-speaking countries, the company was nicknamed *el pulpo*, the octopus, because its tentacles reached everywhere. With considerable justice, it was criticised for monopolising the industry, exploiting labour, and for benefiting only North American shareholders, with profits that were both excessive, and exported.

The company responded well to these criticisms, recognising that they were justified. It developed the Associated Producers Program which gradually converted some of the company into a form of co-operative. Ownership of much of its land was transferred to individual farmers who were given credit and technical assistance. The company then acted as the marketing agent for these private farmers. It also ensured that its workers were paid a decent wage, and were provided with various social amenities such as housing and medical care. In 1970, the United Fruit Company merged with the AMK Corporation to become United Brands.

But, in many areas, these changes were too small, and they came too late. During the 1950s, the Government of Guatemala started confiscating company lands for redistribution to peasants, and, in 1960, Fidel Castro confiscated quarter of a million acres of company land in Cuba without compensation. The company also had disagreements with the governments of Costa Rica and Honduras, which deeply resented their economic thraldom to a foreign commercial organisation, controlled by directors and shareholders in the United States.

Just as the British government was prepared to go to war in support the British East India Company (Chapters 10 & 21), so the United States government was prepared to go to war to support the United Fruit Company. This was usually referred to as ‘sending in the marines’ and these episodes are among the least estimable in United States history.

In its heyday, the United Fruit Company owned huge banana plantations in the countries surrounding the Caribbean. The company supplied all of North America, and much of Europe, with bananas which, due mainly to the company's own activities, had become the most important fruit in the world. Not even oranges or apples were consumed in such large quantities. And the extraordinary thing was that the company was cultivating only *one clone* of banana. In any other species of crop, this would be considered utter lunacy.

Big Michael

Something like a quarter of a million acres were planted with a single clone of an evergreen perennial plant that was growing in a tropical climate which is permanently warm and wet. This was the perfect situation for devastating epidemics of pests and diseases. And yet, the United Fruit Company got away with it. They continued to grow this one variety, exclusively, for about half a century.

This is what was meant by the earlier comment that the banana is an evolutionarily tough plant. The only other cultivated *herbs* that can compare with banana, in this respect, are pineapple, sugarcane, yams, ginger, and horseradish. A clone of potatoes is useless after only a few years of cultivation, unless extraordinary precautions are taken to produce special (and expensive) seed tubers, certified free from disease. Thousands of potato clones have been produced, and then abandoned, because of disease, after being cultivated on relatively small acreages for relatively brief periods. The same is true of most clones of sweet potato, and many other vegetatively propagated crops. But a single banana clone, it seems, can successfully cover vast acreages, and carry on doing so, without a break, for an extraordinarily long period.

This remarkable banana variety used by the United Fruit Company was called *Gros Michel*. This name means ‘Big Michael’, and the name has an obviously obscene origin. The variety is now rare commercially but readers with memories of the 1950s, or earlier, may remember the large, long, and straight bananas that were sold in those days. *Gros Michel* is known as *Pisang ambon* in Malaysia and Indonesia where it is apparently of ancient origin. It was taken to Martinique, in the West Indies, in the early nineteenth century, and it became the basis of all New World commercial banana production. The banana fruits are picked green and they ripen on the ship. One of the commercial advantages of *Gros Michel* was that the stems could be shipped without any packing. The fruit was remarkably resistant to bruising and mechanical damage, and this made its transport very cheap.

However, the United Fruit Company could not get away with this extreme monoculture for ever. *Gros Michel* was obviously highly resistant to any of its old encounter pests and diseases that may have been present in the New World. And there

were no re-encounter parasites. But there were a couple of *new*-encounter diseases. These were minor parasites of indigenous, American relatives of the banana.

The first to appear was called ‘Panama Disease’ and was due to a microscopic fungus (*Fusarium oxysporum* f. sp. *cubense*) that invades the roots and underground stems of the banana plant. The fungus blocks the microscopic water-conducting vessels, and the plant would then suffers a pathologically induced drought, even though there is plenty of moisture in the soil. The fungus also produces toxins which hasten the death of the banana plant.

Panama disease has been called the most devastating plant disease of them all because it destroyed, rather than damaged, so many tens of thousands of acres of banana plantation in the New World. It would be more accurate, however, to call the huge monoculture of a single clone, the most devastating crop vulnerability ever created by man. Not many banana clones are susceptible to Panama disease and the problem was solved once different clones, such as *Dwarf Cavendish*, *Valery*, *Robusta*, and *Lacatan* were cultivated.

The devastation caused by Panama disease was due primarily to the United Fruit Company, and their continuous culture of a single, susceptible clone of banana. We can, perhaps, see the Company's point of view. *Gros Michel* was quite the most popular eating variety of banana. It was in great demand and, possibly, no other variety could have created such a huge market in the industrial world in such a short time. It was also cheap to produce, and cheap to transport. And uniformity of product is a considerable commercial advantage. Nevertheless, no grower of any other crop would ever dream of attempting such an extreme of monoculture for so long.

Joseph Paxton

One of the varieties used to replace *Gros Michel* was the *Dwarf Chinese*. This variety had been introduced to Mauritius from Southern China in 1826, and it was taken to England in 1829 where it was grown in the first glass ‘conservatory’ ever built. Sir Joseph Paxton, who began his career as the head gardener at the Duke of Devonshire's stately home, Chatsworth, had invented a new system of building with iron and glass, and he built his famous conservatory there. This building was so impressive that Paxton was asked to design an even larger one, called the Crystal Palace, in which the Great London Exhibition of 1851 was held.

The new banana flowered in Paxton's conservatory and became one of the wonders of the land. Few people in England, even to today, have ever seen a banana plant. Few people at that time had ever seen a conservatory. Few people, even today, understand that glass is transparent to light but opaque to radiant heat. The light is absorbed inside the greenhouse and radiated as heat, which cannot escape. The greenhouse then gets warm to the point of being tropical. However, no heat is produced during darkness, and little heat is produced by a feeble winter sun. Greenhouses in temperate countries have to be heated during the winter, for this reason.

Paxton's conservatory at Chatsworth consumed vast amounts of coal in the winter and, during World War I, when this amount of coal was unobtainable, it could not be heated. The priceless collection of tropical plants died and, sadly, for reasons of economy, it was decided tear the building down rather than replace the plants. They used explosives to demolish it, but the conservatory was so strong that the first charges merely broke all the glass. To this day, the soil around the site contains millions of pieces of broken glass.

Paxton decided to give a new name to his banana and he called it the 'Cavendish', this being the family name of the Dukes of Devonshire. He also propagated it and gave suckers to all and sundry. The English missionary, John Williams took it to Samoa and, from there, it spread throughout the Pacific. It is also known as the 'Canary Banana' because it is now the main clone cultivated in the Canary Islands. And, as we have seen, it was one of the replacements of *Gros Michel*, because of its resistance to Panama disease.

The main problem with the new varieties that were used to replace *Gros Michel* was that they would not tolerate bruising and mechanical damage. They had to be wrapped, or even boxed, for shipping, and this put up the costs. They were also less productive, and they had smaller fruit that was less popular with consumers. However, the change-over occurred fairly slowly. The prices went slowly up, and the quality went slowly down, and no one seemed to notice.

Moko

The second new encounter disease of bananas in the New World was called 'Moko Disease'. This disease is caused by a bacterium which is a harmless parasite of the *Heliconia* species mentioned earlier, which grow wild in the rain forests of Latin America. But the exotic banana has little resistance to this bacterium which, like Panama disease, invades the water-conducting vessels of the plant and blocks them, producing a pathologically induced drought. Like Panama disease also, the bacterium produces toxins which hasten the death of the plant.

My friend Ivan Buddenhagen, when he was working for the United Fruit Company, showed that the disease could be avoided by surveying virgin land before new plantations were established. If plants of *Heliconia* were found, the land was condemned as unsuitable. If no *Heliconia* plants were found, the land could be used

with safety. However, care had to be taken to ensure that only healthy planting material, taken from a disease-free plantation, was used for establishing the new plantation.

More recently, a re-encounter disease has appeared in Latin America. It is a leaf blight called Sigatoka disease and is named after a small town in Fiji where it was first discovered. The strain known as Black Sigatoka is cause for great concern because it is very damaging, and it is difficult and expensive to control.

Banana Breeding

Unfortunately, the banana is one of the most difficult crops to breed. The breeding objectives are to produce new clones which have adequate pest and disease resistance for cultivation in large plantations and, ideally, the yield and qualities of *Gros Michel*. Plant breeding requires viable pollen and true seeds, and breeding a fruit that is both male sterile and female sterile is possible, incredible though this may seem, but it is not easy. A further difficulty is that most edible bananas are triploids. That is, they contain three sets of chromosomes, rather than the usual two, and this also makes them sterile.

A plant breeder who sets out to breed bananas has a lifetime task in front of him, and his chances of success are not high. Perhaps this, more than anything, indicates what a marvellous job of domestication the ancient cultivators of banana succeeding in doing, and what a very long time ago they did it.

Chapter Twenty

Alcohol

The discoveries of alcohol, and the effects of intoxication, are among the oldest of human processing developments. However, a clear distinction must be made between wines and beers, which are the result of fermentation, and liquors, or spirits, which are the result of distillation.

Alcoholism and Temperance Movements

Alcoholism is an escape, a refuge, for people who live lives of suffering, which may be either emotional suffering, or the strains and stresses of excessive responsibility. In this sense, alcoholism differs only in degree from the opium dens of China (Chapter 21). It was often the man of the house, the wage earner, who spent too much on drink, and incapacitated himself in the process. And it was usually the women who formed temperance movements, trying to cure an obvious evil. Unfortunately, they were trying to cure the symptoms, not the cause.

Alcoholism was particularly bad in the area of North America known as the Bible Belt. Many of the early pioneers, during this period of settlement, had escaped from religious persecution in Europe. Their religion often imposed great emotional stresses on them, and their lives were singularly difficult in the physical sense as well. Clearing virgin land, by hand, to say nothing of building a house from the materials to hand, and starting to farm with little money, in an area with few markets, was difficult at the best of times. The long and arduous winters of Canada and the northern United States made pioneering even more difficult. It is scarcely surprising that many of these pioneers would hit the bottle, to the despair of their wives and

children. Not a few of the wives also hit the bottle. But it was mainly the women, and the preachers, who tried to cure alcoholism by banning alcohol. Their efforts culminated in prohibition, that vast social experiment that was such a failure, and ultimately achieved nothing other than the growth of organised crime.

Similar levels of alcoholism were seen in many industrial countries during the early period of the industrial revolution. This alcoholism occurred mainly among factory workers who were being cruelly exploited, and who often had large families they could not properly support. The people who exploited them, of course, were Social Darwinists (Chapter 4) who pointed to their workers' alcoholism as evidence of their genetic and evolutionary inferiority. Prohibitionists appeared in these societies also.

The prohibitionists never did seem to appreciate the difference between the symptom and the cause, of alcoholism. The cause of the alcoholism was too much stress, in lives that were altogether too difficult. Banning alcohol would not cure this need to escape from stress. The cure for alcoholism is to make people's lives less difficult, and less stressful, with an improved national prosperity, an improved distribution of wealth, and an improved social security. This has been happening at an escalating rate during most of the twentieth century, and both the levels of alcoholism, and the demands for prohibition, have declined accordingly. With further social improvements, alcohol will take its proper place in our society, as a valid pleasure in its own right, and a wonderful aid to conviviality.

Grapes and Grain

As a general rule, wine is made from grapes and beer is made from grain. However, everyone has heard of dandelion wine, elderberry wine, raspberry wine, and so on, although there is some doubt whether these curious fermentations should

be graced with the name of wine. Equally, there are many ‘native’ beers, particularly in the tropics, made from millets, sorghum, and other cereals, and other starches.

When it comes to spirits, brandy is made from distilled wine, and whisky is made from distilled beer (roughly speaking, see below). The old rule is that, when drinking, you should never mix grapes and grain unless you want an unpleasant intoxication, to say nothing of an unpleasant hangover. However, the exception to the rule is that you can drink both, provided that you have a meal in between. It is entirely possible to have a beer or whisky before dinner, wine during dinner, and brandy after dinner, without suffering ill effects.

There is a third category of alcoholic drinks based on ‘neutral grain spirit’ which is, in effect, pure alcohol in water. These drinks include vodka, gin, and rum. If they are of high quality, they can be mixed with each other, and with either grapes or grain. This is the basis of cocktails.

Grapes and Wine

Many species of plant have evolved a sweet and juicy fruit that is an attractive food for animals. This kind of fruit has a remarkable survival advantage for the plant, because the fruit is eaten by an animal which then walks away. Many of the seeds in the fruit survive the animal's teeth and digestive tract, and are dropped to the ground in its dung. When the seeds germinate in the following spring, the dung has weathered to a fine quality manure. The young seedlings then have the double advantage of being widely dispersed and well nourished. From the point of view of the plant, donating some edible tissue to an animal is a small price to pay for such a service.

For similar reasons, many plants produce extravagantly coloured flowers, or penetrating scents, in order to attract insects to a gift of nectar. This gift is a small

price to pay to ensure that the flowers are pollinated. Equally many plants can punish. Stinging nettles, poison ivy, and deadly nightshade are examples of what plants can do to animals that attempt to interfere with them. Punishment and reward are as old as the hills, and were invented long before people even existed. But this is a digression.

The grapevine is one of those plants that donates fruit to a wandering animal. It grows wild in central Asia, in a zone stretching from northern Afghanistan in the East, to the Caspian and Black Seas in the West. Some wild grapevines in this area produce exceptionally juicy fruit which make an acceptable wine. However, these wild vines are variable, and most of them are quite useless for wine making. The first step in the domestication of grapes was to identify, preserve, and propagate the best of them. The cultivation of selected vines began at least six thousand years ago and, possibly, much earlier than that.

Grapes eaten as fruit have been popular since the earliest times, and the modern production of table grapes runs to millions of tons annually. Most modern varieties of table grapes are seedless, and this is obviously a characteristic that could never evolve naturally. Any plant that has lost the ability to produce seed has also lost the ability to reproduce, and the ability to evolve. In nature, such a plant would quickly become extinct. Seedless plants are thus a clear sign of domestication, and they can survive only with the assistance of people. Bananas (Chapter 00), garlic, and yams (Chapter 00) are other examples of domestication leading to the loss of the seed producing ability.

Seedless varieties of grape can be dried in the sun to produce raisins. The top quality raisins are called sultanas, and an ancient Greek variety called ‘Black Corinth’ is still dried to produce very small, black raisins, the so-called ‘currants’ (old French *corauntz* = Corinth) used in making currant buns. (These currants are not related to

the black, red and white currants of vegetable gardens, which are prized for their Vitamin C, and which are species of *Ribes*).

However, these secondary uses of the grape are trivial when compared to its real value which is in the manufacture of wine. Wine occupies such a distinguished place in world literature, religious belief, social custom, history, commerce, and human affairs generally, that it has always seemed more important than mere food. Indeed, wine has arguably aroused more passionate interest than any other plant product. This is partly because of its alcohol although, more plausibly, the interest in wine stems from its power over our taste buds. The flavour of a good wine cannot be equalled by any other food or drink, and the variety of wines with differing but exquisite flavours is virtually unlimited.

It is said that a knowledge of alcohol is one of the first developments to occur in any civilisation, and that human cultures that had yet to discover alcohol were backward indeed. Mild intoxication is often possible by eating over-ripe fruit and, in the old days, farm boys would amuse themselves by making pigs drunk with rotten apples. But fermentation to produce an alcoholic drink requires water-proof pots and, hence, pottery. For this reason, it is thought that the earliest production of wine is unlikely to have predated the earliest production of pottery. Pottery rarely pre-dates agriculture because pots are fragile things and are easily broken. They are also inconvenient to carry around. Nomads, such as hunter-gatherers and herders, would have little use for them. But a few environments were so rich that they allowed hunter-gatherers to be sedentary, and to develop pottery. Japan had such an environment, some fifteen thousand years ago.

However, this suggestion that wine did not pre-date pots is by no means final. Pots can be carved out of timber, and even stone. Large sea shells and cattle horns can also be used when available. Tropical people had coconut shells and bottle

gourds, although these vegetable pots could not hold liquids for very long without spoilage. The use of leather, in the form of ‘wineskins’ is a very ancient one. And, to this day, in Africa, beer is fermented in baskets woven from a reed which swells when wet. When the reeds swell the weave becomes so tight that it is waterproof. It is possible that fermented drinks are far older than we may think, even if the production of high quality wine is impossible without glass or pottery.

The discovery of fermentation is an easy one to make, and it was probably repeated times without number. Fruit juice, after all, is a very pleasant drink, and a welcome change from plain water. Left-over fruit juice will usually become alcoholic after a day or two and, depending on the temperature, will become increasingly alcoholic, and interesting, for up to ten days. For anyone with a rumbustious sense of life, it must have been quite a discovery, that first experience of alcohol, where none had been known before. This was a discovery that would be easily made, and one that would not be easily forgotten.

Archaeological data show that wine grapes were being cultivated in the Near East at least as early as 4000 BC, and the earliest Egyptian record of wine making dates from 2500 BC. Wine was important in the Minoan, Etruscan, Biblical, Greek, and Roman cultures. The Greeks, in particular, spread grape cultivation and wine making to their numerous colonies, which extended from Spain to the Black Sea.

It is perhaps no accident that wine has featured largely in religion. The ancient Greeks regarded intoxication as a form of communion with the gods. They even had a god of wine, called Dionysus (or Bacchus in Rome), and his annual festival was called the Dionysia. The rites of Dionysus were called the *orgia*, from which our own word ‘orgy’ is derived, and they involved both drunkenness, and sexual licence, usually in the open country. The ancient Romans adopted the cult of Bacchus, and they called it the Bacchanalia. But it was perhaps altogether too exciting, and too

disruptive, because it was suppressed by an edict of the senate in 186 BC. The early Christians regarded wine as a natural part of their ceremonies, and it is still used in this way in the Catholic Church. In many cultures, wine has a mystic significance in the drinking of toasts, usually to guests of honour. The Prophet Mohammed so feared the social effects of alcohol that he banned it completely.

Wine also features extensively in literature. The oldest written reference to it is probably in Homer who wrote of wine in 900 BC. Biblical references to vines and wine are common ("So the Lord awaked...like a giant refreshed with wine" *Psalms*, LXXVIII, 66) and ancient Roman authors made frequent reference to wine, perhaps the most famous being Pliny's "*in vino veritas*". Shakespeare said "a good wine needs no bush" referring to the bunch of ivy that was the medieval vintner's sign, because ivy was the symbol of Dionysus. Wine was often the standard of excellence with which other, lesser things were compared.

A knowledge of fermentation is possibly as old as the art of cooking. The most important fermentations are the production of cheese and yoghurt from milk, the leavening of bread, and the production of alcohol from grapes and grain. In alcoholic fermentations, the micro-organisms responsible are yeasts. These are the same organisms that make bread rise (Chapter 6) by converting sugars into carbon dioxide gas and alcohol. Yeasts are microscopic, single celled organisms which reproduce without sex, by a process of cell division. There is a story, quite certainly untrue, that the only time Charles Darwin was known to laugh was when he was told that micro-organisms multiply by division.

The gas that make a sponge out of dough, is the same gas that makes drinks fizzy. The best beers get their fizz from natural carbon dioxide, produced by the fermentation itself. So do the best sparkling wines called *champagne*. This gas is a natural preservative, and drinks which contain it, under pressure, do not need any

other form of preservative. The cheaper beers and sparkling wines, as well as all sorts of non-alcoholic fizzy drinks, have their carbon dioxide gas added artificially. It was a certain Mr. Schweppes, in London, who discovered how to do this. He sold fizzy drinking water under the name of soda water. In the United States, it was known as seltzer, or soda pop. It used to be sold in rechargeable bottles called soda siphons. Later, pressure bottles and crown corks were invented. And sugar was added, as well as various flavours. More recently, the pressure screw cap was developed. But let us return to wine.

Ancient Armenia is believed to be the area in which wine making first developed. The Greeks were the first Europeans to cultivate grapes for wine making and their wines were justly famous during the first millennium BC. Alas, no longer. Modern Greek wines are flavoured with *retzina*, which has a taste of turpentine. This is a taste that can be acquired, and it is one that apparently goes well with Greek cooking but, to most wine lovers, it is anathema.

The cultivation of grapes, and the knowledge of wine making, spread westward from Greece and Asia Minor. It has been suggested that this expansion possibly followed the ancient Phoenician sea routes. The classic European wine producing areas are in river valleys, the Douro, the Tiber, the Po, the Danube, the Rhine, the Rhone, the Gironde, the Loire, the Rhine, and the Moselle, and this river distribution may reflect the original trading limits of Phoenician ships.

It may also reflect a very special feature of the grapevine which is that it is a very drought-resistant plant. Grapevines have very deep roots which can penetrate soil to depths of sixty feet or more. It is possible that grapes thrive in river valleys because these deep roots can reach very low water tables during a dry summer, and these deep water levels, and deep soils, occur typically in river valleys. It is undoubtedly these deep roots that enable the grapevine to produce such large

quantities of luscious, juicy fruit, at the end of a dry and parched Mediterranean summer.

Grapes also occur wild in North America and, although they were not domesticated there, they are of considerable historical interest. The ancient Norsemen, sailing across the northern Atlantic from Greenland to Iceland, and then to the north eastern coasts of America, found wild grapes and, for this reason, called this region “Vinland”. Some of these wild species have been utilised as ornamental creepers, such as the Virginia creeper. As the British botanist Gilbert-Carter said, “Hundreds of miles of suburban architecture are happily hidden in summer by its foliage, which turns red in autumn”.

The American wild grapes indicate that the grape genus evolved before continental drift separated North America from Europe, some sixty five million years ago. The American and Eurasian species of grape are very different in terms of wine making but, nevertheless, they are related closely enough to permit hybridisation and cross-grafting. The American species were also of major historical significance in the European wine industry, as will be related in a moment.

Wine grapes are divided into two categories, usually called black and white, depending on the colour of the grape skin. Black grapes make red wine, and white grapes make white wine. An intermediate wine colour, called *rosé*, is produced from black grape juice when the skins are removed before fermentation.

The most famous variety of red wine grape is probably ‘Cabernet Sauvignon’. This is the classic grape of the Bordeaux vineyards on the River Gironde, which produce the wine known in Britain as claret. ‘Pinot Noir’ is the variety of Burgundy, which has wines with such famous names as Chambertin, Pommard, Nuits St.-George, Meursault, Beaune, and Montrachet. The most famous white wine varieties are ‘Chardonnay’, grown in Burgundy, Chablis, and Champagne,

‘Johannisberg Riesling’ grown in the Rhine and Moselle Valleys, and ‘Chenin Blanc’ grown in the Loire Valley.

These are classic grape varieties, which cannot be matched by any product of modern plant breeding. Each of these varieties is a clone, propagated vegetatively from cuttings or grafts. Fewer than twenty of these clones dominate the eleven million hectares (twenty six and a half million acres) of vineyards in the world, and are responsible for famous wines produced in areas as far apart as Europe, California, South Africa, Chile, and Australia. In addition to the classic wine grapes, there are an estimated ten thousand lesser varieties of wine grape in the Old World, but these are mostly of purely local interest.

An ancient discovery that was closely associated with wine making was the bottle cork. This was made from the bark of the cork oak (*Quercus suber*) which, along with the chestnuts, is a member of the beech family (*Fagaceae*) and, as would be expected from its history, is a native of the Mediterranean area. This tree has a particularly thick bark which regenerates after being stripped off. The bark is cut into individual corks which are air-tight, and water-tight, when inserted into wine bottles. Corks usually require a special machine to insert them, and a corkscrew to extract them. There is now a world shortage of bottle cork, and many wine bottles are sealed with plastic stoppers, screw caps, or crown corks.

Wine will not normally keep after the bottle is opened because it becomes contaminated with micro-organisms, which cause a secondary fermentation that reduces the alcohol to acetic acid. The spoiled wine is known as vinegar. This word is a corruption of the old French *vyn egre*, now spelled *vinaigre*, which is itself a corruption of the Latin *vinum acrum*, which means acid, or sour, wine. The knowledge of vinegar is as old as the knowledge of wine itself, and vinegar has many

uses in cooking. As with lemon juice, it is used to give a sharp 'bite' to the food, and to reduce the greasiness of fried foods.

When wine is distilled, it produces the spirit called brandy. The best brandies are French, being produced in Cognac and Armagnac, and are named after their places of origin. By law, these brandies must be aged in oak casks and, for each year of ageing, the brandy is awarded a star. Five-star brandy has thus been aged for five years.

Some wines are strengthened by the addition of brandy, and they are then known as 'fortified' wines. The strongest wines have about twelve percent alcohol, and natural concentrations higher than this are not usually possible because the alcohol becomes poisonous to the fermenting yeasts. Fortification of wine increases the alcohol concentration artificially, usually to about twenty percent. The original purpose of fortifying wine was to improve its drinking quality, by increasing the alcohol content, but a secondary purpose was preservation. Fortified wines do not spoil after opening, because the alcohol content is so high that no micro-organisms can survive in it.

The best fortified wines come from Spain and Portugal. The Portuguese wine is produced in the valley of the Douro River, and is known as port, which is an English corruption of Oporto, the town from which the wine is shipped. Another Portuguese reinforced wine is produced in the island of Madeira. It dominated the wine taste of Americans for two centuries because it was taken on board after the ships had left London and, consequently, it was not subject to British taxes in the bad old colonial days.

The reinforced Spanish wine is produced in the city of Jerez, in Andalusia, in Southwest Spain, and is known as sherry, which is an English corruption of the name Jerez. Sweet sherries are dark, and dry sherries are pale. Other fortified wines are

flavoured with herbs, and are called aperitif wines, or vermouth, and they may be red or white, and sweet or dry. Quinine (Chapter 21) may be added to vermouth to give it a bitter flavour. Famous vermouth names include Campari, Dubonnet and Martini.

Recently, the opposite process, involving wine *dilution*, to produce 'coolers', has become popular. Coolers consist of wine diluted with a fizzy drink to reduce the alcohol concentration to about four percent. This is the alcohol concentration of most North American beers, and coolers permit considerable thirst quenching without serious intoxication. Many coolers are additionally flavoured with one or more fruits, such as peach or pineapple. Wine dilution, usually with mineral water, at the table, is an old and common practice, particularly in Italy, but the sale of bottled, fizzy, diluted wine is new.

Although wine has been fermented for many millennia, the process of fermentation has been understood for little more than a century. The process was elucidated by the famous French chemist, Louis Pasteur (1822-1895), who had a scientific career that was one of the most productive ever known. Pasteur started as a chemist. Then he became a biologist. This led him to veterinary science and, finally, to medicine. In medicine, he found the means of preventing hydrophobia, the lethal disease that develops in people who have been bitten by a rabid dog.

In veterinary science, Pasteur solved the problem of anthrax, an infectious disease that killed farm animals, particularly sheep. And in microbiology, he discovered that all fermentations were due to micro-organisms, including the harmful ones that turn both wine and milk sour.

This was a discovery of great significance, because science at that time was split into those who believed in "spontaneous generation" and those who denied it. Those who supported it believed that micro-organisms could be generated out of nothing, that they were a *product* of putrefaction. Pasteur showed that the

micro-organisms had to be present in the first place, and that they were the *cause* of putrefaction. He discovered that a nutrient broth could be heated and, if protected from the contaminating dust of the atmosphere, it would not go bad. This was the beginnings of his *germ theory* which was to revolutionise biology and medicine.

Pasteur's germ theory enabled Joseph Lister, in Scotland, to develop anti-septic (now called aseptic) surgery. In those days, there were few kinds of surgical operation. The main ones were lancing an abscess, and amputating a broken limb, usually only after gangrene had set in. This kind of surgery had mortality rates of up to seventy percent. Opening the abdominal cavity was considered to be little short of murder, because it was invariably fatal. Surgeons even spoke of ‘laudable puss’ because, if a surgical wound was suppurating, this was at least a sign that circulation continued, and gangrene was unlikely. Lister’s contribution to medicine was a direct result of Pasteur’s germ theory. His contribution medicine is perhaps equalled only by that of Alexander Flemming, who discovered penicillin, and inaugurated the age of antibiotics.

In Pasteur’s youth, bottled wine was often found to be bad, or ‘corked’, and it was undrinkable. This explains the tradition of the wine waiter smelling the cork. He does this to ensure that he is not offering a bad wine. The host tastes it first to satisfy himself that it is a wine good enough for his guests. The myth that the host must publicly taste the wine in order to demonstrate that it is not poisoned, is nonsense.

Pasteur was asked to investigate this problem of spoiled wines, and he showed that it was due to undesirable ‘germs’ which ruined the wine. He recommended that the newly sealed bottles of wine should be heated, not quite to boiling point, in order to kill these germs. This process is now known as *pasteurization* and it is used routinely on products such as wine, beer, and milk.

Curiously, Pasteur also found the explanation for a process that had already been known for half a century. This was the method of preserving food, by a combination of sealing and heating, which had been discovered, in France, by Nicolas Appert, in 1809. Appert's discovery eventually led to a huge and entirely new industry called the canned food industry which, in its turn, led to a new and huge demand for tinned sheet steel.

There was another aspect of Pasteur's discovery of the role of micro-organisms in fermentation. Some microbiological processes, such as fermentation, were desirable but often would not occur. It was largely a matter of chance whether the necessary micro-organism was present or not. It was also a matter of chance whether highly deleterious, contaminating micro-organisms were present or not.

Pasteur showed that the undesirable micro-organisms could be destroyed by pasteurization, and that the desirable micro-organisms could be maintained in pure cultures, and then added to the pasteurised ferment. Anyone who has used a beer kit for making home brew, will be familiar with the small packet of yeast that is added to the carefully sterilised wort when it is ready. All modern fermentations of wine, cheese, and beer are controlled in this way.

It seems that the ancient Romans knew empirically about the pasteurization of wine without, of course, understanding the reason for it. It seems also that they used to pasteurise their wine in lead vessels, and that people who routinely drank such wine would eventually die of lead poisoning. It has been suggested that this was a contributory cause in the collapse of the Roman Empire. It was mainly the aristocracy who were killed in this way, and there was eventually an acute shortage of educated people, capable of doing the work of government.

In 1860, a problem far more serious than bottles of spoiled wine began to rock the European wine industry, quite literally to its very roots. The classic wine grapes in

the Rhone Valley began to die. The leaves would change prematurely to yellow, and then red and, eventually, the entire vine would wilt and die. This was less than twenty years after the potato blight disaster (Chapter 11). By 1868, thousands of hectares were affected and a certain Monsieur Planchon had identified the cause. It was an insect, a species of aphid, which inhabited the roots. The aphid was called *Phylloxera vitifoliae* and it was a native of America. The American wild grapes were very resistant to the aphid, but the European grapes were highly susceptible.

This was a 'new encounter' parasite. The host and the parasite had evolved separately, in different continents, and they had been brought together by people. Ironically, they had been brought together by scientists who were doing experiments involving the hybridisation of European grapes with wild, American grapes. When they imported the American vines, these scientists unwittingly imported the *Phylloxera* also. And, as a result, the European wine industry was soon faced with total ruin.

In 1870, the Prussian army invaded France and the war was so destructive, and aroused so much resentment, that, if a Frenchman wanted to insult a dog, he would call it a German. Nevertheless, it is believed that the *Phylloxera* caused greater economic loss than the Franco-Prussian war. Eventually, about one million hectares of French vineyards were ruined, and people began talking of the final demise of wine. This was a time of deep tragedy for France, with her defeat in war, the loss of Alsace and Lorraine, and the loss of her most treasured industry, her wine. The tragedy soon extended beyond the borders of France, and the *Phylloxera* spread to North Africa, to South Africa and Australia. The disaster seemed unending.

The problem was solved by a cosmopolitan naturalist who was born in London, schooled in France and Germany and who emigrated to the United States at the age of seventeen. His name was Charles Riley and he later became the first official

entomologist of the State of Missouri. He was the first to recognise that the *Phylloxera* was an American species of insect. He also recognised that this was the main reason why the classic wine grapes of Europe had failed when their cultivation was attempted in the United States. And he developed the technique of grafting the classic wine grapes of Europe on to American rootstocks that are highly resistant to *Phylloxera*. This saved the European wine industry, as well as the classic European varieties of grape. It also made their cultivation possible in North America as well.

Many wine connoisseurs claimed that vines grafted on to wild grape rootstocks produced an inferior wine. This claim is somewhat doubtful and, in any event, the difference was so small that only a connoisseur could detect it. Nevertheless, the best vintages dating from before 1860 continued to be treasured in cellars all over Europe. These 'pre-*Phylloxera*' vintages became increasingly rare, and increasingly valuable until, around 1930, they were past their best and had started to decline.

Possibly the saying that it never rains but it pours developed out of what happened next. In the 1870s, rootstocks from America were imported into Europe in great variety, and in great quantities. Millions of grafts were made and the vineyards were replanted. Inevitably, with all this importing of foreign vines, another new encounter parasite was also imported. This was the downy mildew, caused by a microscopic fungus *Plasmopora viticola*, that is closely related to the potato blight fungus (Chapter 11). The wine industry was only just recovering from *Phylloxera* when it was assaulted a second time. The downy mildew was possibly even more damaging than the *Phylloxera*, because it attacked the vine leaves directly, and killed them, usually in a few days. Once again, people were talking of the final demise of wine.

Then, as we have seen (Chapter 11), in 1882, Professor Millardet, who had done much to stimulate the grafting that saved the vines from *Phylloxera*, was

examining mildewed vines in the famous Médoc area of Bordeaux, when he noticed that some of the vines at the Château Beaucaillon were green and healthy. These vines were growing near a road, and their owner had sprayed them with a poisonous-looking substance to discourage passers-by from eating the grapes. The substance was a mixture of copper sulphate solution and lime and, by chance, it was a perfect fungicide. This was the discovery of Bordeaux mixture, the first fungicidal spray for crops.

It was only years later that the chemical mechanism of Bordeaux mixture was discovered. This compound of copper and lime is very stable, and it is almost completely insoluble. It is certainly not sufficiently soluble to be poisonous to people, or to the plants it is sprayed on, or even to microscopic fungi. How, then, did it work?

As we now know, when a microscopic spore of *Plasmopora* or *Phytophthora* germinates, prior to invading a leaf, it excretes a waste product which the chemists call a chelating compound. This chelation makes the Bordeaux mixture sufficiently soluble to be toxic to the fungus, while it remains non-toxic to both the plant and to people. In effect, with its own excretory waste products, the fungus commits suicide by activating a minute amount of the otherwise innocuous Bordeaux mixture.

It is perhaps worth commenting that, before these new encounter parasites arrived in Europe, grape clones were highly resistant to all their locally important parasites. And, because many of these clones were centuries old, and possibly millennia old, this resistance is clearly durable. The resistance of the American rootstocks to *Phylloxera* is also durable. The resistance of European grapes proved inadequate only against new encounter parasites.

There is a rather sad, modern sequel to the *Phylloxera* story. It was discovered that classic grapes, grafted onto resistant rootstocks, yield rather less than when they are on their own roots, in the absence of *Phylloxera*. So scientists in California started

experiments with hybrid rootstocks, produced by crossing American vines with classic wine grapes. These scientists obtained considerable increases in yield with a hybrid called AxR#1. Nearly 20,000 hectares of vineyard are now planted with this hybrid rootstock in the Napa and Sonoma valleys. Unfortunately, the original research, which led the selection of this rootstock on the basis of yield, made no attempt to test its resistance to *Phylloxera*. And this resistance is poor. It is about halfway between the high resistance of its American parent, and the high susceptibility of its European parent. And this halfway position is not good enough. The *Phylloxera* develops more slowly on these hybrid rootstocks, but it still develops. The 20,000 hectares of AxR#1 vineyards now have to be uprooted, fumigated, and replanted, at a estimated cost of nearly one billion dollars.

Barley and Beer

Barley was domesticated at about the same time, and in the same area, as wheat. Originally, barley was grown as a food and, in some areas, it was preferred to wheat. As we have seen, barley was the preferred crop in much of Mesopotamia, because it is more tolerant to salty soils than wheat, and the ancient irrigation practices of the Tigris-Euphrates Valley civilisations had led to considerable soil salination. However, barley contains no gluten and, for this reason, it cannot be made into bread, like wheat and rye. Equally, it does not have the free-threshing character of wheat, and removal of the husks is difficult. Early farmers soon decided that wheat was best for bread, and that barley was best for beer.

The brewing of beer from barley was common among the early Egyptians and Mesopotamians, and it dates from at least eight thousand years ago, probably pre-dating wine. It eventually became important mainly in those areas, such as northern Europe, where grapes cannot be grown. From the earliest records of brewing, it was

known that the barley should be germinated before being fermented, in a manner similar to Chinese bean sprouts. This process of germination is called ‘malting’ because, in the process of germinating, all the insoluble starch in the grain is converted to soluble sugars, collectively known as malt. After malting, the grain is dried in warm air, ground into grits, and it is then ready for *mashing*, by boiling with several times its volume of hot water. After mashing, the liquid is filtered off and is known as *wort*. The malt can be extracted to produce a thick, viscous, and very sticky liquid that is canned and retailed for making home-brew. The spent barley grains are dried and sold as an additive to animal feed.

The wort is then boiled with hops and it is here that there is most variation in beer recipes. The mixtures of different hops, and the quantities used, offer nearly as many different combinations as metal alloys. Originally, hops were used as a preservative but, in modern beers, they are used primarily for flavour, and they add mainly bitterness. The hopped wort is cooled and it is then ready for fermentation.

The fermentation of beer is done with a yeast called *Saccharomyces cerevisiae*, and there are many different strains of this yeast, with different brewing characteristics. During fermentation, the yeast multiplies, using the soluble sugars in the wort as nutrients, and producing alcohol and carbon dioxide as waste products. The beers known as ales and stouts are produced with a warm fermentation in which the yeast floats. These are often called ‘top fermentation’ beers. Conversely, lagers are fermented at a lower temperature, and the yeast sinks to the bottom to produce a ‘bottom fermentation’ beer. But different strains of yeast, and different hops, are also used in each kind of beer. The dark beers, such as stout, obtain their colour from barley that has been roasted.

Many modern breweries use a continuous fermentation process in which raw ingredients are slowly, but constantly, added at one end of the tank, while finished

products are constantly removed form the other end. Most breweries also have trade secrets concerning processes that control many of the finer qualities of their beers, such as flavour, colour, and shelf-life. Some breweries now produce beer concentrates, by freezing the beer and removing the ice crystals. The idea is to save transport costs, and the concentrate is reconstituted by adding both water and carbon dioxide in a bottling plant at the distant destination.

During much of this century, the commercial breweries have been getting bigger, with increasingly monopolistic tendencies. They also tended to employ more and more artificial additives and techniques that made beer production both cheaper and quicker. Unfortunately, these techniques produced an inferior beer, and people began to compare commercial beer to commercial bread. Nothing could equal the home-made product. For this reason, home-brew beer kits are now as popular as bread making machines. In Britain, an immensely successful organisation called CAMRA (*Cam*paign for *R*eal *A*le) was formed to encourage the brewing and sale of high quality beers. Many small breweries were opened, and British pubs discovered that this was the beer that their customers really wanted. Sheer public demand has defeated the monopolistic tendencies of the big breweries and, once again, it is possible to obtain excellent beer in British pubs. A similar revival is now occurring in Canada and other countries. However, this was never necessary in Germany which has a beer purity law that insists that *nothing* made be used to make beer, other than water, barley, hops and yeast. Britain has a comparable law which prohibits the removal or addition of *anything*, but this law refers to milk. Both of these laws have led to problems in the unification processes of the European common market.

Beer is quite the most popular of the alcoholic beverages, and nearly fifteen billion gallons are now produced annually, worldwide. About one quarter of this is

produced in the United States. Germany and the United Kingdom are the next largest producers, and each produces about a tenth of this total.

Whisky (often spelled whiskey in Ireland and the United States) is made by distilling fermented grains, and storing the distillate in wooden barrels. Only four countries have traditional whisky industries, producing whiskies which are accordingly known as Scotch, Irish, Canadian, and American.

Scotch whisky is produced by distilling a fermented ‘mash’. This mash is a malt wort which, however, contains no hops. Like all traditional beverages, Scotch whisky is a product of the country’s history. Scotland is too far north, and it cannot easily grow either hops or cereals, other than oats and barley. The mash is made with malted barley that was dried over a peat fire and this gives it a very characteristic, smokey, peaty flavour. The best Scotch whiskies are the single malts, which are each the product of an individual distillery, and they have usually been aged in wooden barrels for at least five years, and often twelve years. Blended Scotch whiskies are a blend of several single malts with neutral grain spirit, and the more expensive of these are also aged in casks for up to twelve years. The Japanese drink a lot of Scotch, but it is whisky that is made in Japan, and it is a very close copy of the genuine article. Irish whiskeys are similar to the Scotch whiskies except that the barley is not dried over smokey fires.

Canadian whiskies are made from mashes that contain various proportions of maize, rye, wheat, and malted barley, depending on the brand in question. The American Bourbon whiskey was first produced in the Bourbon county of Kentucky. It is made from maize which can be employed either as a sour mash, or a sweet mash. The sweet mash uses only new yeast, while the sour mash uses both fresh and old yeast, taken from an earlier brew. The sour mash process is similar in this respect to the sour dough of bread making.

By United States law, straight whiskies are named after the grain they are made from, and these grains must make up at least half of the mash. Thus straight malt whiskey, straight rye whiskey, straight bourbon, and so on. Blended American whiskeys are mixtures of straight whiskeys.

Perhaps mention should also be made of gin and vodka, which are neutral grain spirit that is usually distilled from a potato mash. Gin is flavoured with juniper berries and, sometimes, other herbs. Schnapps and Holland gin (or *genever*) are closely similar. Rum is made from molasses (Chapter 17). There are also a number of highly flavoured, sweet alcohols known as liquers, mostly of French origin. They include Benedictine, Grand Marnier, Cointreau, Creme de Menthe, and both green and yellow Chartreuse.

Chapter Twenty One

Drug Producing Crops

Most societies which are in the early stages of cultural development have medicine men, or witch doctors, whose ability to heal depends very heavily on a knowledge of medicinal plants. And our own modern sciences of medicine and pharmacology have very strong, and very ancient, foundations in a knowledge of botany. About twenty five percent of all drugs have a botanical origin, and a few species of drug plant have remained sufficiently important to be cultivated as commercial crops. The word ‘drug’, of course, refers to both pharmaceuticals and the good of the illegal drug trade.

Opium

The ancient Greek physician, Pedanius Dioscorides (40-90AD), travelled over much of the known world as a surgeon with the armies of the Roman Emperor Nero. From his experiences, he wrote a work called *De Materia Medica* which became a classic, and remained the leading pharmacological text until the seventeenth century. In it, he describes no less than six hundred species of plants reputed to have medicinal properties, and four hundred other drugs derived from mineral sources. His botanical descriptions were so excellent that they became the foundation of modern botany.

Dioscorides describes two anaesthetics which he said could be given to a patient to subdue pain during surgery. One of these is derived from mandrake (*Mandragora officinarum*), a member of the potato family (*Solanaceae*), and a native of the Mediterranean region. Mandrake has a forked root which vaguely resembles

the human form. In medieval times, it was widely believed to have magical properties, and it was used to induce sleep and pregnancy, and as a love potion.

But it was also believed that a mandrake would utter a diabolical shriek if pulled from the ground, and that anyone who heard this shriek would go mad, or even die. The plant could be safely harvested only in moonlight, with appropriate prayers and rituals, and by harnessing it to a black dog in order to pull it from the ground. However, all the bother was not really worthwhile, because mandrake is not a very effective anaesthetic.

The other anaesthetic recommended by Dioscorides was opium which was a very ancient medicine, even in his own day. There are Sumerian records of opium dating from 5000-4000 BC, and Assyrian tablets that refer to its medicinal value. Homer mentions it, and this indicates that it was known to the Greeks in 900 BC. Hippocrates was using it in 400 BC. Galen (130-200 AD), whose books became the final authority of a closed-minded and stagnant medical profession for centuries in the West, was also a keen advocate of opium.

Opium is extracted from a poppy called *Papaver somniferum* which was domesticated from a wild poppy, *Papaver setigerum*, in Asia Minor, at least six thousand years ago. The drug is prepared by making several shallow incisions in the green seed capsule, which is the size of a small walnut. A white latex, similar in appearance to raw rubber (Chapter 12) is exuded and, as it dries, it turns brown or even black. This is the opium itself which must be rubbed off the seed capsule.

Raw opium usually comes in lumps or as a powder, but it may also be formed into bricks. It can be administered directly as an oral medicine, either as a solid, or as a tincture, which is a solution of raw opium in alcohol, known as laudanum. For centuries, opium has been a boon to medicine in soothing severe pain, inducing sleep,

and as a cure for diarrhoea. It was only during the last hundred years that synthetic and superior alternatives began to be available.

In modern pharmacology, the drugs extracted or derived from raw opium are called opiates, and they have valuable and legitimate uses. The active ingredients consist of some twenty different alkaloids which are classified into two groups. One group is defined by its effects on the nervous system and includes morphine, codeine, and thebaine. These alkaloids are sleep-inducing (narcotic), pain-killing (analgesic), and addictive. The other group, which includes papaverine and noscapine, have none of these properties, but they do relax the involuntary muscles, which are the muscles of the lungs, heart, and viscera.

Morphine can be chemically modified to produce a drug called di-acetyl-morphine, otherwise known as heroin. This drug was developed by the Bayer Company of Germany in 1898, and it was introduced to medicine because it is several times more powerful than morphine in its narcotic and analgesic effects. However, it is highly addictive, and the addiction is difficult to cure. It also has side-effects which are so dangerous that its use is no longer permitted in medicine. But, as everyone knows, it has illegitimate uses also, and it is one of the main items of the illegal drug trade.

Contrary to popular belief, it is very difficult to define addiction, because it can be caused in so many different ways, and degrees, to so many different drugs. It is possible to develop a mild addiction for sugar, for example, but no one would seriously call sugar an addictive drug. Similarly, many people enjoy regular doses of nicotine (Chapter 18), caffeine (Chapter 14) or ethanol (Chapter 20) and partake of these pleasures regularly, without being considered drug addicts. Indeed, there are very few social occasions in which some form of drug, whether it is tea, coffee, alcohol, or tobacco, is not provided for the guests. And a failure to provide them

would be regarded as a grave breach of hospitality. Equally, a mild dependency on synthetic drugs, such as sleeping pills, tranquillisers, anti-depressants, and pain killers, is sanctioned by society and is not normally considered to be addiction.

Perhaps the chief characteristic of addiction to ‘hard’ drugs is that addicts become physiologically dependent on their drug. This is because many of their body tissues have so altered themselves in response to the drug that they can no longer function normally without it. This is sometimes called a chemical, or physiological, dependence.

There is also a psychological dependence which can be powerful and urgent. The most common aspects of psychological dependence are the reduction of anxiety, the relief of emotional stress, the lifting of depression, and the search for elation. There are thus both positive and negative aspects of psychological dependence. The negative aspects involve escapism, away from the harsh realities of a world that the addict can no longer tolerate. The positive aspects are a state of euphoria that becomes desirable to the point of being indispensable.

Another characteristic of addiction to the opiates is the phenomenon of physiologic tolerance. As the body develops tolerance to a drug, the effects of that drug are diminished. It is then necessary to take increasingly large doses to re-experience those original effects. Tragically, for the addict, one of the effects of tolerance is that those original effects never can be resuscitated entirely. In spite of increasing doses, there are declining effects. In the case of morphine, people can develop a tolerance to 5000 milligrams a day, and obtain almost no effect from it, when the clinical dose for a non-addict is 5-20 milligrams a day. This, of course, is the real horror of opiate addiction. The addict needs more and more of the drug which, being illegal, is extortionately expensive, while the drug itself steadily reduces the ability to earn the money to pay for it.

There are only two possible escapes from this increasingly desperate situation. The first is death and, for a hopeless addict, a deliberate and lethal overdose can be very tempting. The second is a clinical cure, but this is both slow and painful. There is a close parallel with a diver coming up from great depths, and great pressure, who must be brought to the surface very slowly, otherwise the nitrogen dissolved in his blood will form bubbles, and cause a horribly painful condition known as the 'bends'.

Similarly, an addict being cured of his physiological dependence must be weaned very slowly otherwise he is liable to suffer withdrawal symptoms which can be even more horrible than the bends. He must spend time in a clinic being given smaller and smaller doses each day until his physiological dependence is back to zero. The psychological dependence is even more difficult to cure. One of the sadder aspects of drug addiction is the way in which it destroys the willpower and, consequently, an addict is usually quite unable to cure himself.

For most of its history, however, opium was used solely for medicinal purposes, and its use was entirely beneficial. After they conquered Asia Minor, in the seventh century, the Arabs controlled most of the opium trade. They made great use of ships for trade purposes, and this enabled them to establish a wide area of sea-borne trade. This included the Mediterranean and the whole of Europe, North Africa, the Indian Ocean, including East Africa, Persia, and India, and, eventually, in the Pacific Ocean with China. There was also a very ancient overland trade route to China known as the silk route, which also came under Arab control at its western end.

As we saw in earlier chapters, the most profitable items of this Arabian trade were black pepper from India, and silk from China, and the main market was Europe. The Arabs established a powerful monopoly in these items and maintained it for more than seven centuries until their Indian Ocean navy was destroyed by the guns of Vasco da Gama in 1503. The Arabs introduced opium to both India and China in the

eighth century and, for the next seven centuries, it was grown in Southeast Asia exclusively for medicinal purposes.

Curiously, the factor that first changed opium from a legitimate and useful medicine into an illegitimate and dangerous drug, resulted from the discovery of America. The Portuguese had established a trade route with China via the Indian Ocean, and the Spanish had established their galleon trade across the Pacific Ocean from Acapulco to China, via Manila in the Philippines. Both the Portuguese and the Spanish were looking for items of trade, other than gold and silver, that might interest the self-sufficient Chinese, and that would help pay for the silk that was in such demand in Europe.

One of these new items of trade was a crop from the New World that was a novelty in both Europe and China. This was tobacco (Chapter 18). However, it never did become an important item of trade with China because the Chinese soon learnt how to grow it for themselves, and they became self-sufficient in tobacco as well.

But the Chinese did make one very significant discovery. They mixed opium with tobacco and showed that opium could be smoked. This was the first ‘hard’ drug. To its users, it was mind-bending, escapist, addictive, soul-destroying, irresistible, and, finally, lethal. The Chinese developed a new kind of club, known derogatorily in English as an opium den, in which users would both purchase and smoke their opium. Opium dens became places of social horror, where it was often the breadwinner of a large family who would remain incapacitated for long periods, earning nothing, spending everything, and finally dying.

For about three centuries, from 1550 onwards, the seafaring nations of Europe and later, but to a lesser extent, the United States, had an adverse balance of trade with China. This was because China was the sole source of those two articles of luxury, tea (Chapter 13) and silk. Until the industrial revolution, the Western nations

produced nothing that the Chinese wanted. The only way they could obtain tea and silk from China was to pay with gold or silver.

It was the Portuguese who, in the early eighteenth century, discovered that huge profits could be made from trading opium with China, even though the trade was illegal because, in 1729, the Chinese Emperor Yung Cheng had prohibited both the sale and the smoking of opium. However, Imperial edicts against opium were largely useless because of widespread corruption in the Chinese bureaucracy. And modern governments have learnt how difficult it is to stop an illegal drug trade.

Some fifty years later, most of the opium smuggling was conducted by the British East India Company which, very conveniently, had a monopoly of opium production in India, as well as a monopoly of British trade with China. But France and the United States were also involved, using opium grown in Turkey.

These Western nations deliberately fostered an illegal trade in a hard drug in order to solve their balance of payments problems. They created in China exactly the problems of drug trafficking and drug abuse that we are now struggling so hard to control in the West. There was one difference, however. The illegal opium trade with China created social problems several orders of magnitude worse than any drug abuse problems we now have in the West. To Europeans, the very idea of the opium den became almost synonymous with the nation and people of China.

For the Chinese, the opium trade, with its associated opium dens, must have been far worse than our modern problems with cocaine, crack, and heroin. First of all, the quantities of drug, and the numbers of people adversely affected, were far greater. Second, the drain of Chinese wealth was huge. Third, the total misery and human suffering, associated with the opium dens, and the loss of family incomes, was appalling. Lastly, these were tribulations imposed by foreign governments concerned

only about their adverse balance of trade, and who thought nothing of forcing this affliction on the Chinese people.

Opium dens even appeared, and were often tolerated by the authorities, in China Town areas of San Francisco, Los Angeles, Vancouver, and other ports around the world. The Chinese addicts in these towns were usually indentured labourers, imported for work on the railways. Many had been forbidden to bring their wives or families, and they were far from home, and desperately lonely. The authorities considered them third class citizens, and were not seriously concerned if they died of their addiction.

In 1725, 200 chests of opium were sold to China each year. Fifty years later, the annual sale was 1000 chests. In 1825, it was 10,000 chests and, by 1838, it was 40,000 chests. This was a two hundred-fold increase in little more than a century and, at last, the balance of payments swung in Britain's favour. But the Manchu government of China finally took decisive action and insisted that all foreign merchants surrender their stocks of opium for destruction. In 1839, the Chinese confiscated and destroyed 20,000 chests of opium. The British were furious, and they started a military campaign which became known as the first opium war.

Although it was the Chinese who had invented gunpowder in the tenth century, when Europe was only just emerging from the Dark Ages, and it was the Chinese who made the first bronze cannon during the Yuan Dynasty, in the thirteenth century, when Europeans were still fighting with bows and arrows, the European armaments of the nineteenth century were far superior to the Chinese. The opium war went badly for China which, in 1842, sued for terms.

Humiliating conditions were exacted. The opium trade remained technically illegal but the Chinese agreed to stop their efforts to prevent it. Trading rights and British enclaves were established in five ports, a huge indemnity was claimed, and the

right of British nationals to be tried in their own courts was established. Following the British victory, other Western nations demanded, and obtained, similar concessions. Like the British, they too behaved with the arrogance of the ancient Romans subduing a primitive tribe.

The second opium war was started in 1857, on a trivial pretext, by connivance between the British and French, who easily overcame the Chinese. The Treaty of Tientsin, legalizing opium, was signed, but not ratified. After a renewal of hostilities, a party of French and British officers and interpreters, who had gone to the Chinese camp to negotiate an armistice, was imprisoned by the Chinese, and taken to the Summer Palace in Peking.

In those days, the Chinese treated their prisoners with oriental indifference, rather than cruelty, and they often left them lying on the ground, bound hand and foot, to die. When the British conquered Peking, they found that many of the negotiating party had died in this way. To punish the Chinese Emperor, the British commander decided to destroy some of Tsieng Feng's most treasured possessions. So he burned the Summer Palace, which was one of the great triumphs of Chinese architecture, and a treasure house of Chinese art. The Manchus later built another one, known as the New Summer Palace. But the Old Summer Palace, and its priceless collection of treasures, are gone for ever.

This British commander was James Bruce, Eighth Earl of Elgin. He was the son of Thomas, the Seventh Earl, who was the Lord Elgin famous for his removal of Greek sculptures from the Athenian Acropolis, now in the British Museum, and known as the Elgin marbles. There is no doubt about it. Theft, drug trafficking, and arson, on the grand scale (of course), are seemly and fitting occupations for noble lords.

Ironically, with the development of tea production in India (Chapter 13), and the increasing trade with China in industrial goods, especially armaments and railway components, the balance of trade swung permanently in the favour of the Occidental nations during the second half of the nineteenth century. Eventually, by mutual agreement, the opium trade was reduced, and it finally ceased entirely in 1917. However, the opium trade was callously started up again by the Japanese, when they conquered Manchuria, following the deliberately faked Mukden Incident in 1931, which some historians regard as the starting point of World War II.

Opium for the illegal drug trade is now produced mainly in 'The Golden Triangle' of northern Thailand, northern Laos, and eastern Burma. This remote and mountainous region is difficult to police, and drug traffickers can easily escape pursuit by crossing an international border. Opium is a labour-intensive crop and it is cultivated by peasants who often have no other source of income. One of the great challenges facing modern crop scientists is to find an alternative crop for these peasants, and one that is both legal, and as profitable, as opium. They have not succeeded, although saffron (*Crocus sativa*) shows some promise in this respect.

Another source of opium is Turkey where, after all, the crop has been grown for millennia. Many areas in this country are also remote, mountainous, and difficult to police. And, once again, the peasants who grow this opium have no alternative crop as a source of income. Sadly, it is not the peasants but the traders who make the huge profits from the illegal trade in opiates. The extraction of morphine, and its conversion to heroin, is not difficult chemically, and can be undertaken in quite a simple laboratory, hidden in an unsuspicious building.

Much of this Turkish opium reaches North America and Europe, as illegal morphine and heroin, via Sicily and the Mafia connection. Much of the Golden Triangle opium is handled by Chinese traders operating out of Singapore, Hong

Kong, and Macao. The tables have finally turned, and the illegal opium trade is now in the oppsoite direction.

Coca

Coca is a New World drug plant that was well known to the Incas and, indeed, was their nearest medicinal equivalent to opium. They used to chew coca leaves for this purpose, and the drug was also used during religious ceremonies. The plant is a shrub called *Erythoxylum coca* and it must not be confused with the entirely different cocoa (*Theobroma cacao*) which is the source of chocolate and is described in Chapter 15. Coca is native to South America, and it occurs wild on the western slopes of the Andes in Bolivia, Chile and Peru. It is, of course, the source of the drug cocaine.

The first contact that Europeans made with coca was when Francisco Pizarro (1560-1637) conquered the Inca civilisation which, in those days, was a coastal empire extending from the southern border of modern Colombia, through Ecuador and Peru, to central Chile. This is a distance of more than 2000 miles. Pizarro had explored this coast by ship in 1524-1527 and he was reporting in person to the King of Spain when, as it happened, Cortés was also present, telling the King of his conquest of Mexico and the Aztecs. Pizarro obtained permission to undertake a similar conquest of the west coast of South America.

The Incas were themselves conquerors who had only recently established their empire of some ten million people. This empire was, in some ways, remarkably similar to the ancient Roman Empire. It was authoritarian, hierarchical, efficient, and brutal. The Incas had acquired excellent standards of building in stone from their subjugated peoples, and these are still visible in various palaces, fortifications, and irrigation systems.

Like the Romans, the Incas also had a system of communications which, in that area, and at that time, was unprecedented. It consisted of a network of roads which, in fact, were narrow tracks designed for human runners and llamas used as pack animals. The Incas had no horses or donkeys for riding, and no wheels or vehicles of any sort. Their messages were sent by human runners, who would run in relays. Each runner had to be physically fit. And he had to have a good memory, because the Incas had no writing, and he carried a memorised, verbal message.

Chewing coca leaves helps people to overcome physical and mental fatigue, without food and drink. Coca might have been specially designed for the Inca communications system, which depended on human runners who, by chewing coca leaves, could obtain relief from fatigue, increased mental alertness and memory retention, increased physical strength, and a reduction of hunger.

When Pizarro conquered the west coast of South America, he had only three ships and a few hundred men but, like Cortés in Mexico, he had horses, steel armour and, above all, guns. The Inca empire had also been greatly weakened by re-encounter human diseases (Chapter 5). Pizarro captured the chief Inca, Atahuallpa and held him to ransom for a room filled to the ceiling with gold and silver. When he had got his precious metal, Pizarro broke his promise, and he told Atahuallpa that he would to be crucified unless he became a Christian. After Atahuallpa had been baptised, Pizarro broke his word again, and he hanged Atahuallpa. He then melted down priceless art works to produce bullion.

These Spanish conquerors of the New World civilisations, such as the Inca and Aztec cultures, were ruthless and grasping marauders. Pizarro later murdered his partner, Almagro, whose son then murdered Pizarro, under brutal circumstances, in 1541. But the Inca empire had been destroyed for ever.

Cocaine was first isolated chemically in 1860 and it has been used in Western medicine since 1884, as a local anaesthetic in dentistry and minor surgery, and as a tonic for the digestive and nervous systems. The leaves of the coca plant contain about one percent cocaine. These leaves are picked 3-4 times a year, and the annual yield is up to 2000 pounds of dried leaves per acre. The dried leaves have been a traditional item of trade, sold for chewing, within the eastern countries of South America for centuries. Coca is also cultivated commercially, and legally, for medicinal purposes, chiefly in Sri Lanka and Java. It is also cultivated illegally, mainly in Bolivia and Colombia, for the illicit drug trade.

In its pure form, the drug is a fine, white, crystalline powder known colloquially as ‘coke’ or ‘snow’. There are two methods of administering the drug. The more popular is to sniff it into the nasal cavity through a paper tube, but repeated use can do permanent damage to the mucous membranes.

The alternative method is an intravenous injection of a solution of cocaine. The great danger of this method is the possibility of contracting AIDS and other diseases, such as hepatitis, from an unsterilised needle.

Injection of cocaine leads to a very rapid and intense ‘high’ which, however, is of short duration. The real problem with cocaine is that this ‘high’ is usually followed by depression, and this prompts further use of the drug. More recently, a modified form of cocaine, called crack, has come into use. Crack is produced by cooking cocaine with baking soda. The drug effects are then greatly increased, and they are much cheaper. Unfortunately, crack is very addictive, and it is dangerous.

Cocaine is also dangerous because an overdose will depress the entire nervous system, and this can lead to respiratory failure and death. Prolonged use of cocaine can also damage the heart muscles. Cocaine is habit-forming and it can induce chemical and psychological dependency in some individuals, though not to the extent

of crack, or the opiates. Physiological tolerance is much less than with heroin and, consequently, increased doses are less necessary. Withdrawal symptoms may develop with some individuals but they are relatively rare and mild. Cocaine is thus much less dangerous than heroin. However, in large doses, it is intoxicating and causes excitement, mental confusion and, eventually, convulsions.

Excessive and chronic use of cocaine can lead to a severe loss of appetite, emaciation, inability to sleep, personality disturbances, and an increased tendency to violence and anti-social acts, accompanied by paranoid delusions. Hallucinations become frequent, particularly the curious and unpleasant impression of ‘bugs under the skin’ which has led to many colloquial expressions for the less pleasant aspects of drug addiction, such as ‘the creeping heebie-jeebies’, and ‘the screaming ab-dabs’.

Kola

Kola is a genus of trees, native to West Africa, and belonging to the same botanical family as cocoa (Chapter 15), the *Sterculiaceae*. This tropical family evolved before continental drift produced the Atlantic Ocean, some sixty five million years ago. The family is thus represented in both Africa and South America but, because the two portions of the family were geographically isolated from each other by the separation of the continents, entirely different species evolved in each land mass. However, kola was taken to the Americas at the time of the slave trade.

The harvestable product is a nut which is of interest mainly because it gave its name to a class of soft drinks. It is probable that the original cola drinks obtained their colour and flavour from kola nuts. Originally, these drinks contained small amounts of cocaine which, at that time, was thought to be a harmless and preferable alternative to alcohol. Their stimulating effects may also have come from the kola nuts which are unusually rich in caffeine.

But, today, the production of bottled colas is so vast, and the cultivation of kola nuts is so small, that it is most unlikely that modern colas contain kola. If they did, in significant amounts, the world acreage of kola nuts would very likely be as great as that of tea (Chapter 13) and coffee (Chapter 14) combined. Equally, the use of cocaine stopped at the beginning of this century. The recipes of most modern cola drinks are jealously guarded trade secrets, but the fact that many of them are advertised as being free of caffeine also suggests that their connection with either kola nuts or coca leaves is historical and linguistic only.

Kola nuts are popular in West Africa, and some of the West Indian islands, where they are chewed. In addition to caffeine, they contain a glucoside called kolanin, and people who chew them have an enhanced ability to withstand fatigue. Kola is prized by travellers and labourers, and it has social and religious uses. An ancient trade in kola used to be important, mainly to the northern, and drier, parts of sub-Saharan West Africa. This trade determined many of the old routes for the camel caravans of the Housa merchants, who travelled to the caravansaries of such remote, and inaccessible, desert towns as Timbuctoo, and Sokotoo.

Cannabis

Cannabis sativa is known as Indian hemp and it is possibly the first fibre plant ever to have been domesticated for spinning, basket making, and cloth production purposes. The fibres, gathered from wild plants, have been used since Neolithic times, and the plant has probably been cultivated in China and Central Asia, for fibre production, for more than six thousand years. It is still cultivated in many countries for its fibres, although competition from synthetic fibres has greatly reduced its importance.

The hemp varieties which produce fibres are tall, with few branches, and few flowers and seed. They produce fibres up to seven feet long which were used mainly for the production of yarns and ropes, but also for coarse cloth such as canvas. Other, quite different, varieties of cannabis are short, with many branches, numerous flowers and seed, and are cultivated for the sake of their drug content.

Cannabis is native to China and Central Asia where wild plants are common to this day. It is a relative of the stinging nettle, and its drug effects were recorded by the Chinese as early as 2800 BC. The drug became known to the Europeans at the time of the Crusades, when it was called hashish.

This term ‘hashish’ is a corruption of an Arabic word meaning a ‘dried herb’. The drug was associated with a Muslim political and religious sect which was founded by a Persian, Hasan-e-Sabbah. The members of this sect considered it a religious duty to murder their enemies. The Crusaders called them the Assassins, which is a medieval corruption of the Arabic *hashishi*, which means ‘hashish-eaters’. The name ‘assassin’ was taken to Europe by the Crusaders, in the eleventh century, and this word entered various European languages as a synonym for murderer, although it usually has a strong implication of political, rather than personal, motive.

The worst enemies of the Assassins were the Christian Crusaders themselves. The Crusaders greatly feared the Assassins, and believed that they took hashish before committing their murders. This gave cannabis a bad name. It also led to the popular myth of the drug fiend, a ruthless and fearless monster, crazed with drugs, on the rampage, killing all and sundry with inhuman brutality.

The myth persists even though it is well known that virtually all drugs are soporific. People who are planning murder want to be fully alert, not dopey with drugs. Drugs rarely induce aggression or hyperactivity. They mostly induce

taciturnity and sleepiness, and their effects are usually the very opposite of criminal violence.

The Assassins lost power at the time of the Mongol conquests in the thirteenth century. But the sect still exists, with entirely peaceful followers, throughout the Middle East, and hashish is still widely available in that area.

Hashish can be eaten, usually mixed in some form of confection, or it can be smoked. A small fragment of hashish is placed on a piece of glowing charcoal in a tobacco pipe, and the smoke that is immediately produced is quickly sucked through the pipe and inhaled. The hookah, or water pipe, is popular for this purpose because it cools the smoke which is otherwise rather hot.

The active ingredient of cannabis is a complex substance called tetra-hydro-cannibol, often abbreviated to THC. It is located in the resin which occurs in the glandular hairs of the cannabis plant. Very few localities, and very few varieties of cannabis, are capable of growing a plant rich enough in resins to produce hashish, which consists of pure resin. The maximum resin production occurs in a hot, dry climate, when pollination is prevented by removal of the flowers, and the plants are dwarfed by cutting off the top leaves.

Charas is an Indian form of hashish which also consists of the pure resin. Hashish and charas are about eight times as powerful as other forms of cannabis, which consist merely of dried plant parts, and are often known as ‘hay’ or ‘grass’ for this reason.

In India, ‘grass’ is called *bhang* or *ganja*. *Ganja* is the more potent because it is prepared with the flowering tops of the plant, which contain the most resin, and it comes from specially cultivated plants of a special strain of the cannabis plant. The name is now widespread in the West Indies. *Bhang* is the least potent of the Indian

preparations because it does not include the flowering tops of the plant. It is either drunk as a tea or smoked. It is frequently used in Hindu religious ceremonies.

The commonest name for grass in the New World is the Spanish term, *marijuana*. The word means, simply, “Mary-Jane”. *Marijuana* varies considerably in its potency, depending on the variety, where it was grown, and how it was treated and stored. Grass is usually smoked by rolling it into a cigarette, called a reefer. It can also be inhaled like snuff, chewed like tobacco, or ingested, after it has been added to food or drink.

Law enforcement officers have been known to spray illegal crops of cannabis with a phenoxy weed killer called 2,4,5-tri-chloro-phenoxy acetic acid, otherwise known as 2,4,5-T. This herbicide often contained excessive amounts of a highly toxic impurity called dioxin. Tragedy ensued when the owners of the crop would harvest it as soon as the law enforcers had left, and before the plants died. This poisonous material would then find its way into the illegal street trade, and its smokers would obtain a lethal dose of dioxin. Law enforcers now use a safer herbicide which also contains a red dye to colour the treated plants, and to warn smokers of possible danger.

There is a spectrum of cannabis effects, with ingested hashish at the most powerful end, and smoked bhang at the other. The hashish end of the spectrum is closely similar to LSD and is hallucinatory. A physiological tolerance to THC does not develop and, consequently, the temptation to increase the dose is slight. Chemical dependence does not occur and there are no withdrawal symptoms. There is a psychological dependence with a few users which, however, is not difficult to cure. For this reason, it is usually much easier to give up cannabis than, say, tobacco or alcohol.

Until the turn of the century, *marijuana* was freely available in pharmacies and was popular as a folk medicine in the United States. *Marijuana* is a very mild substance which requires considerable practice before its full effects are achieved. It is only a mild hallucinogen and, contrary to popular belief, it is not necessarily the first step in an irreversible descent to heroin. As a means of reducing tension and inducing a sense of well-being, *marijuana* is safer, and less damaging, than alcohol.

Nevertheless, regular smokers of *marijuana* among the young can ruin their lives. It has not yet been established whether the *marijuana* was solely responsible for this, or whether it was merely a contributory factor in a psychological decline that was happening anyway. On the other hand, many young smokers of *marijuana* participate only because of peer pressures, and they have little difficulty in dropping the habit later.

Students who are regular smokers of *marijuana* often feel fine for the entire semester, but they are shocked when they achieve low grades, having never realised how little they were learning. If they continue to use *marijuana*, they are liable to lose an entire segment of their developmental process, and they may even become members of a lost generation. However, to put this tragic situation in perspective, it must be noted that young alcoholics are far more seriously at risk.

A special aspect of modern *Cannabis* cultivation is the development of new cultivars with greatly increased THC content. This was achieved by plant breeding and, obviously, this breeding was unofficial and illegal. It was done by amateurs. And this is of interest to potential amateur breeders of other crops for horizontal resistance. This is exactly what I have recommended in my book *Return to Resistance* (available as free download at www.sharebooks.ca) as the best means of overcoming the pernicious desire of the pesticide and seed companies for *susceptible* cultivars. Organic farmers and eaters of organic food please note.

Quinine and Aspirin

For three hundred years, following its introduction to the Old World by the Spanish, quinine was the only known drug that was effective against malaria. Quinine is extracted from the bark of a South American tree called *Cinchona*, and it is a highly effective curative drug, which can also be used as a preventative. However, excessive use is likely to lead to a lethal complication called black water fever. It was this disease, more than any other, that gave West Africa its reputation as “White Man's Grave”. Since World War II, quinine has been replaced by less dangerous synthetic drugs.

Quinine was also used to make a soft drink called tonic water. The quinine gave a bitter taste, and a bluish sheen, to the water, but it was not present in sufficient concentration to prevent or cure malaria. Tonic water became very popular for mixing “gin and tonic”, and it was erroneously believed by English people living in India that it was necessary to get this drink into one’s bloodstream before the malarial mosquitoes starting flying after dark. Hence the term “sundowner”. Quinine is also used to give a bitter taste to some fortified wines (Chapter 20).

During the eighteenth and nineteenth centuries in Europe, quinine was very expensive and poor people often used willow bark as a substitute, because it was just as bitter as *Cinchona* bark, and it was the bitterness that was thought to be effective. In fact, willow bark is not effective against malaria but it does contain a compound called salicin, named after the willow genus *Salix*. Salicylic acid was introduced to medicine in the 1870s, and its even more effective derivative, acetyl-salicylic acid, was discovered in 1899.

This substance became known as ASA or aspirin. It completely replaced laudanum as a pain reliever, and it is now produced synthetically. Strong doses of

aspirin reduce pain and swelling, and are useful against headaches, colds, and influenza. Milder doses are apparently useful in reducing blood cholestrol, blood clotting, and blood pressure. Taken regularly, aspirin can thus reduce the risk of heart attacks and strokes. The fact that the United States alone consumes some 25,000,000 pounds of ASA each year indicates how safe and useful it is.

Betel Nut

Betel nut is the fruit of a palm tree (*Areca chaechu*) that has been cultivated since antiquity in Southeast Asia, particularly in India, Burma, Thailand and Malaysia. Today, it is chewed by people from the East African coast to the islands of the Central Pacific. It is likely that more people chew betel nut than use chewing gum. Unlike chewing gum, betel has drug effects, and it is habit forming.

Although betel may be chewed on its own, it is usually chewed as a carefully prepared ‘quid’. Small pieces of betel nut are wrapped in a leaf of betel pepper, a botanical relative of black pepper (Chapter 10), with a dash of slaked lime, and the quid is chewed slowly but not swallowed. Other substances which may be added to the quid include tobacco (Chapter 18), cardamoms, and cloves (Chapter 10).

Like chewing-tobacco, betel causes continual salivation and chewers need to spit frequently. Unlike tobacco, however, betel turns the saliva red, and betel chewers have never heard of spittoons. The walls and sidewalks in betel-chewing towns are always stained red for this reason.

Khat

Khat is the bark of a small tree (*Catha edulis*) that grows wild in East Africa. It is now cultivated in Tanzania, Kenya, Ethiopia, and Yemen, both for local use and for export to the Persian Gulf. The East African name for the drug is *miraa*, and it is

prized locally by people undertaking physically difficult tasks, such as crossing a desert on foot. The effects of the drug are similar to those of benzedrine.

Perhaps the most important effect of khat on people in the West is that its cultivation has largely replaced coffee cultivation in the Yemen. This means that the Mocha variety of coffee, which is the finest of them all, is no longer available.

Aphrodisiacs

The word aphrodisiac is derived from *Aphrodite*, the ancient Greek goddess of love and fertility. An aphrodisiac is anything that stimulates sexual desire and sexual performance, and aphrodisiacs can be loosely classified into two classes, the psychological and the physiological.

Psychological aphrodisiacs are mostly in the category of sympathetic magic, being derived from an object that has a shape reminiscent of sex organs, such as the phallic asparagus. As such, they are not without effect on the gullible, particularly if they are difficult to obtain, and very expensive. Rhino horn is a classic example. In the days when spices were rare and expensive in Europe, they were all believed to have aphrodisiac qualities. Another less well known example is the double coconut (*Lodoicea maldivica*) which occurs only in the Seychelles, in the Indian Ocean. The plant is a palm, and it produces the largest seed in the world. Each nut weighs 40-50 pounds and has the appearance of an enormous pair of testicles. When the nut germinates, it produces a stalk that resembles a penis. In the past, the nuts were only rarely found floating in the Indian Ocean, and they would fetch a high price as an aphrodisiac in places such as Zanzibar.

Physiological aphrodisiacs are ingested as food, drink, or drugs. Some of them, such as alcohol or cannabis, can be effective simply by reducing or removing inhibitions. Others are reputed to increase sexual powers and, more specifically, to

restore waning sexual powers in the elderly. One of these is the *yohimbé* tree (*Corynanthe yohimbe*) in Central Africa. The bark of this tree contains an alkaloid called yohimbine that is supposedly an aphrodisiac. Use of the bark for this purpose is undoubtedly a very ancient tradition in that part of the world, but it is thought that the effect is more psychological than physiological. A more direct effect can be obtained by rubbing on hot spices, such as pepper or chilies, that induce skin flushing, and a sense of warmth. However, the margin between a sense of warmth and a sense of burning, to the point of pain, even blistering, is a very narrow one, and these substances must be used with caution.

Perhaps the most famous aphrodisiac of all is the cantharides beetle, otherwise known as the blister beetle. There are several thousand species of blister beetle, many of which secrete an irritant called cantharidin. The best known species is the Spanish fly (*Lytta vesicatoria*) and, in the days when the raising of blisters was considered a medical cure for many ailments, its cantharidin was in demand. In those days also, people made great use of love potions which would supposedly enamour an otherwise indifferent loved one. Cantharidin was one of the more popular ingredients of these love potions and, to this day, Spanish fly is widely believed to have aphrodisiac properties. However, modern synthetics, such as Viagra, are so effective that they have replaced all these natural sources. This is undoubtedly the best way to save the rhinos.

Chapter 22

The Future

Any serious consideration of the future must be based on those three brutal laws of nature that have dominated human history and pre-history and, indeed, the whole of evolution. Having emerged from Africa and colonised the entire world, there is nothing more we can do to increase our total environment. However, we can still increase the carrying capacity of that environment, quite dramatically. And we can control our population size, quite dramatically also. And we need to do both of these things, fast.

Let us first consider the carrying capacity of the environment. Any geographer will tell you that, if every government agency had all the land it needed, a country such as England would have to be ten times its present size. First is agriculture, and there is no way that the agriculture of England can feed the population of England. Next is urban planning, including housing, industry, shopping, leisure industries, sports, and so on. Then there is transport, and the network of roads and railways, car parks, ports, and airports. Environmentalists clamour for wilderness areas, and civic authorities need landfill sites. There seems to be no end to the demand for land.

There seems to be no doubt that we would have plenty of land if only we could find an alternative to agriculture. And, it must be admitted that agriculture is a ludicrously inefficient method of producing food. Productivity varies, of course, but, on average, only 0.1% of the solar energy that falls on agricultural land is actually ingested by people as food. And, if there is a two-step process, in which crops are produced to feed animals, in order to provide meat for people, the efficiency is reduced to about 0.005%.

So we now have an extraordinary comparison. On the one hand, modern agriculture is so efficient that it has increased the carrying capacity of our environment to about one thousand times that of our pre-scavenging, plant-gathering, hominid ancestors. And, on the other hand, modern agriculture is so incredibly inefficient that less than one thousandth of the solar energy falling on our fields becomes human food.

It seems that we may now be on the verge of a new breakthrough even more important than the discovery of agriculture itself. This breakthrough will depend on an entirely new method of domestication. Everyone has heard of it, new though it may be. It is called genetic engineering. Consider a factory, rather like a modern brewery, with fermentation tanks containing genetically engineered micro-organisms. These micro-organisms might be producing pure starch, in a continuous culture like penicillin, day and night, year in year out. In one year, this factory, which occupied one hectare of land, could easily produce a couple of thousand tons of starch. That would make it one thousand times more productive than the North American wheat lands.

This figure is perhaps difficult to grasp. In terms of land use, modern industrial fermentations, using genetically engineered bugs, could be one thousand times as efficient as agriculture. And agriculture itself is one thousand times as efficient as a wild ecosystem providing plant food to pre-scavenging hominids.

So how realistic is this suggestion? In a sense, it is beginning already. We are now producing complex pharmaceuticals with genetically engineered micro-organisms, and it is only a matter to time before research costs come down sufficiently to permit the production of more mundane, cheaper substances. Such as starch, sugars, fats and oils, and various kinds of protein.

Many people will raise their hands in horror at this suggestion of 'synthetic' food, produced in factories. But, if we can produce complex pharmaceuticals in this way, we can also produce the various minor components of foods, such as wheat gluten, that contribute to the textures and flavours that we know and love. It is entirely feasible to envisage bread made from factory produced ingredients that is every bit as delicious as home-made bread derived from wheat and other natural flours. And the bread made from factory ingredients would certainly be no worse than many of the modern commercial breads (not that this is any great recommendation).

When I was a child, just before World War II, all sorts of food shortages were threatening, and people were talking of food 'substitutes'. In Germany, these were called *ersatz* foods. Saccharin was a sugar substitute, and there was a despised butter substitute, called margarine. This was the time when Goering made his famous "guns or butter" speech. But attitudes change and, today, many attitudes have been reversed. Not a few people now *fear* real butter, and real sugar. Much the same has been happening with modern textiles, plastics, and detergents. And it could happen equally with foods produced by genetically engineered bugs.

So it seems that we are about to conquer that brutal law of nature concerning the carrying capacity of our environment, finally and conclusively. At least with regard to food, that is. But once food is eliminated as a limiting factor, other limiting factors will appear. We simply cannot afford to continue reproducing to the limit of that new carrying capacity. We must also conquer that other brutal law of nature which demands that all species reproduce in excess of the carrying capacity of the environment.

Here again, it is reasonable to look into the future and postulate important new technical developments. It is entirely possible that new techniques of contraception will become so easy, so cheap, and so effective, that infertility will be the norm. A

couple wanting a child would have to plan the conception several weeks ahead. It would not be in any way difficult to conceive a child, but it would require deliberation and forethought. Given a minimum of government regulation, this would achieve two things. First, our population size would be stabilised. And, second, the birth of *unwanted* children would all but cease. It is these unwanted children who grow up without emotional security, to become neurotic, possibly psychotic, and probably criminal. And it is these unwanted children who tend to be abused, and who themselves grow up to be abusers.

This misery of unwanted children is consistently ignored by the anti-abortionists, and the religious, who claim that contraception interferes with the will of God. Any biologist can tell you that the will of God always has been that third brutal law of nature, which says that every species must reproduce beyond the carrying capacity of its environment. This book is not the place for either philosophical or theological discussion. Whatever philosophical or theological conclusions anyone may wish to draw, the *biological* conclusions are irrefutable. We must control out population size if we do not want our descendants to suffer tragedies of unparalleled magnitude.

So let us envisage a time when our population size is stabilised, and not too large, and a time when our food supply is unlimited. Let us assume also that there are no more unwanted children, and that all children are loved, and grow up with physical and emotional security. And that vast areas of agricultural land are liberated for other purposes, such as decent housing, beautiful towns, parks, forests, and wilderness areas. This could be a simple but effective formula for worldwide peace and prosperity, and the final, successful vanquishing of all three of those brutal laws of nature, by a single species that has had the temerity to call itself *Homo sapiens sapiens*.